OBITUARY

BROTHER MARIE-VICTORIN, D.Sc., F.R.S.C.

Brother Marie-Victorin, of the Christian Brothers, director of the Botanical Institute of the University of Montreal and of the Botanical Garden of the city of Montreal, and a member of the Board from 1929 to 1937, was killed in an automobile accident on the fifteenth of July, 1944, while returning from a botanical excursion to Black lake, Megantic county, Que. He was in his 60th year. Botany was his main field of activity, so that this association with the Board was almost purely academic and incidental.

It is actually premature to estimate the value of his scientific contribution. But he certainly has added much to the botanical knowledge of North America, through his extensive explorations of the flora of eastern Canada, which resulted in the publication of an imposing number of papers and memoirs, and of the "Flore laurentienne", a quarto book of over nine hundred pages, profusely illustrated with original drawings from nature, and embodying a wealth of personal and varied information till then unpublished. Although taxonomic and descriptive botany form the most obvious part of his technical writings, they have nevertheless been for him but a means of elucidating problems of geological, ecological or genetic nature. Strongly impressed by the dynamic and evolutionary aspects of the organism communities, he has given many proofs of how these forces have been acting upon the eastern Canadian floras.

Marie-Victorin has played a leading rôle in the recent development of scientific education in a province where humanities and liberal arts had always been the too exclusive background of any intellectual activity. He was directly responsible for, or has taken an active part in, the foundation of many lasting and fecund educational and scientific enterprises: the *Botanical and the Geological Institutes* of the University of Montreal; the *Société Canadienne d'Histoire Naturelle*, of which he was Chairman for fifteen years or so, giving annually carefully thought out and elaborated presidential addresses, each of which was a daring and authoritative appeal to action and progress; the local *Association for the Advancement of Sciences*, a federation of all the French scientific bodies of the Province, which has been highly instrumental in promoting the development of scientific education and research in this part of the country; the *Junior Naturalists' Clubs*, actually numbering nearly six hundred, scattered all over the Province, with a total membership of about thirty thousand school boys and girls; finally, and perhaps his most important and promising accomplishment, the *Montreal Botanical Garden*, an achievement of long, arduous and clever effort.

Marie-Victorin, before being a scientist, was a *man*, a great scholar, of universal understanding, moved by the artistic and poetic manifestations of the human mind as well as by the scientific ones, and on whom any racial discrimination or prejudice could have no hold. And this, after all, might be the finest and most useful lesson he has left to his disciples, to his University colleagues, to his compatriots, to his countrymen. And may this lesson bear fruits and be everlasting!

GEORGES PRÉFONTAINE.

The State of the West Greenland Current up to 1944

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ABSTRACT

Temperature records from the mouth of Godthaab fjord, west Greenland, during 1942-1944, show a cooling of the water over these three years, particularly marked in the first half of the year. The temperature history of the west Greenland current is traced by means of available records since 1883. It is found that warmer conditions existed during the decade of 1880, followed by a colder period up to about 1920, when the present warm period began. The peak of the present warm period appears to have been reached in the middle 1930's, and it is possible that the cycle is about to return to colder conditions, with a weakening of the Atlantic component of the current.

INTRODUCTION

The gradual change in climate during recent decades in arctic and subarctic regions, from west Greenland across the north Atlantic to Siberia, has been described by several workers (Scherhag 1936, 1937, 1939; Brooks 1938; Loewe 1937; Jensen 1939). The change consists of a rise in sea and air temperatures and a retreat of the southern limit of sea-ice. Scherhag (1937) ascribes the warming effect to an increase in strength of atmospheric circulation, and on the basis of an examination of Easton's (1928) coefficients for west European winters since the year 1235, concludes "that it appears to be a question of a secular period in the variation of atmospheric circulation of some 225 years duration, which seems at this juncture to have attained its maximum."

The west Greenland current is composed in part of water from the east Greenland polar current and in part of Atlantic water from the westerly branch of the Irminger current which turns, west of Iceland, towards the southeast coast of Greenland and in rounding cape Farewell mixes with the east Greenland polar water. In southwest Greenland there are further additions of Atlantic water from the Labrador sea. For figures on the volume of the current in 1928 at different levels along the coast, calculated with reference to the 1,500-decibar surface, see Smith, Soule and Mosby (1937). The retreat of the ice and the weakening of the arctic water, and the strengthening of the Gulf stream, have thus resulted in a warming of the west Greenland current in recent years, causing important changes in the marine fauna, including the commercial fishes (Jensen 1939). The transport of floe ice (the Danish "Storis") by the east Greenland current round to the west coast since 1820 has been reviewed by Speerschneider (1931), showing a marked decrease in the quantity of ice carried round since

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about 1910, and in the distance to which the ice reaches to the north along the west coast of Greenland. A temporary return to colder conditions in 1937 in the southwest was recorded by Hansen (1939), which was repeated and accentuated all along the coast in 1938. Warm conditions returned in 1939 (Hansen 1940).

As is shown below, the warming effect is now discernible at least as far north as Upernavik (figure 1). The present paper is concerned only with the upper 300 metres of the west Greenland current, and in particular with the upper 100 metres, that part of the current which is of the greatest importance biologically and meteorologically, and which consists of water showing coastal influences. Above a depth of about 150 metres, salinities are normally below 34 ‰, and there is dilution in the upper layers both from melting ice and from land drainage, the extent of which varies seasonally. It is in this water that the effect of varying arctic and Atlantic influence is most striking.

TEMPERATURE RECORDS

The material collected here is intended to show two different processes—the annual temperature cycle in the upper layers at one point in west Greenland (Godthaab fjord), and the temperature history of the coastal current to the extent that earlier records permit. The annual cycle has not been investigated hitherto, our knowledge being restricted to information obtained by short expeditions, usually in the summer. The present state of the current is thus projected from two sections in time—the section across the year, which is repeated annually, and the section across comparable times of year along the period from approximately 1880 to 1944.

Salinities are not included in this account. As was to be expected, salinities in Godthaab fjord, in all but the superficial layers, increased during the spring and summer as the temperatures increased, confirming the seasonal growth of Atlantic influence. In agreement with the increase in salinity parallel with temperature in the deeper water during the summer, an increase in salinity during recent years, accompanying the warming of the west Greenland current, was reported by Loewe (1935) for Umanak fjord.

The temperature records from Godthaab fjord were kept as frequently as other duties permitted, and with the equipment available in wartime. The lack of winch and wire except for a short period in 1943 and 1944 made it impracticable to go deeper than 75 metres as a rule. The records from the mouth of the fjord, taken within four miles (1 mi. = 1.6 km.) of the colony of Godthaab, are shown in table I. Table II includes three stations made further north, off Godhavn in July 1942, off Upernavik in August 1942, and in the Vaigat in September 1943. From the 1942 series in table I it is apparent that the temperatures increase gradually from as early as March and April, implying an increasing amount of Atlantic water flowing up the coast. Continuous surface cooling causes unstable conditions during the winter, and vertical interchange may continue from the fall to the early spring. The most violent interchange appears to take place in October, when fast cooling at the surface diminishes the contrast in density between the surface water and the deeper layers, and in

FIGURE 1. Map of the west Greenland coast from cape Farewell to Upernavik. Heavy rings denote areas from which stations were taken for temperature comparisons in figures 2-6.

TABLE I. Temperatures in °C. at the mouth of Godthaab fjord, 1942-1944.

1942 Date	II 20	III 14		IV 30	VI 19					X 8	X 19	X 31	XI 5	
Depth (m.)														
0	0.76	0.89		1.46	5.90					0.68	0.10	2.10	1.90	
10	0.90	1.00		1.70	3.57					1.68	1.00	2.18	1.91	
25	1.00	1.06		1.64	3.35					2.88	1.83	2.19	1.97	
50	0.90	1.17		1.61	2.50					3.04	2.42	2.21	1.90	
75	1.00	1.21		1.61	2.41						2.57	2.21		
1943 Date					VI 17	VI 30	VII 13	VII 24	IX 2		X 20	X 28		XII 13
Depth (m.)														
0					1.90	2.73	6.99	7.27	4.69		0.94	0.96		0.04
10					1.90	2.50	5.18	4.44	3.78		1.51	1.06		
25					1.71	2.41	3.43	3.05	3.60		2.05	.		1.06
50					1.32	2.26	2.66	2.85	2.97		2.25	2.45		1.16
70					1.32	2.45	2.65							
75								2.70	2.84		2.55			
100												2.75		1.26
200														1.90
300												3.25		
1944 Date			IV 21	V 3			VII 16		IX 11					
Depth (m.)														
0			0.85	0.76			5.21		4.68					
10			0.75	0.52			3.35		2.55					
25			0.60	0.49			3.05		2.45					
50			0.48	0.24			2.67		2.27					
75			0.46				2.30		1.90					
100				0.31										
250				0.61										

TABLE II. Temperatures in °C. from Godhavn, Upernavik and the Vaigat.

Station	Two miles west of Godhavn, one mile from shore	Four miles south of Upernavik, approximate position 72°43′N., 56°11′W.	Vaigat, approximate position 70°00′N., 52°20′W.
Date	July 31, 1942	August 30, 1942	September 15, 1943
Depth (m.)			
0	6.83	3.50	3.65
10	5.93	2.92	3.47
25	2.03	1.67	2.85
50	1.93	1.30	3.25
75	1.43	1.01	2.43

the early spring, when similar unstable conditions are achieved by the surface cooling of the warmer water coming up the coast. An upwelling in October is clearly evident between October 19 and 31, in 1942, and a spring upwelling is illustrated in the figures for June 17 and 30, 1943. In 1942, surface heating had stabilized the upper layers by June, the figures for June 19 showing strong solar

effect in the upper 10 to 25 metres. This effect was retarded, however, in 1943, when considerable warming of the surface water was not evident until July. There was a similar lag in the increase in temperature in the deeper layers (25 to 75 metres) in 1943, compared to 1942. This lag is also shown in the April and May figures for 1944, when the water in all layers was considerably colder than at a comparable period in 1942. Early autumn cooling of the deeper water in 1944 is also suggested by the temperatures recorded on September 11, 1944, showing lower figures than both 1943 and 1942. Cooling of the deeper water in the autumn, failing evidence of vertical interchange with water cooled at the surface, must be due to decrease in the Atlantic element in the coastal water of the west Greenland current. Cooling of this type, as is shown in table I, was apparent in October 1942 (between October 8 and 19), between September 2 and October 10, 1943, and in September 1944.

The high temperature (3.25°C.) at 300 metres on October 28, 1943, is in agreement with the known characteristic of the west Greenland current, namely the presence of underlying warmer water of high salinity (over 34 ‰), at depths below about 150 metres. In this connection, the difference between this temperature in October, 1943, and the 250-metre figure (0.61°C.) on May 3, 1944, is remarkable. The overall pattern to be obtained from table I is one of a marked decrease in temperature at the mouth of Godthaab fjord over the years 1942-1944, particularly in the first half of the year. There are strong indications that this fall in temperature is due to a decrease in the strength of the Atlantic component in the coastal water.

The three stations shown in table II are used below in comparison with earlier records of other workers. The temperatures at Godhavn in July, 1942, with the exception of the sun-warmed surface layers, were considerably below the June figures for Godthaab, but by September, in 1943, the temperatures in the Vaigat were of the same order as the Godthaab figures for the same month.

The comparison of temperature records from west Greenland during the last sixty years has been done by means of the temperature curves shown in figures 2 to 6. The material for these curves has been taken from all the available literature, made up of the reports both of small individual expeditions sent out from Denmark and of larger enterprises such as the Swedish "Sofia" expedition of 1883 (Hamberg 1884); and the Danish "Fylla", "Ingolf", "Tjalfe", "Dana" and "Godthaab" expeditions (Wandel 1891, Knudsen 1898, Nielsen 1928, Conseil Permanent 1926 and Riis-Carstensen 1936). Material is also taken from the results of the Norwegian "Michael Sars" expedition of 1924 (Martens 1929), and the United States Coastguard "Marion" and "General Greene" investigations of 1928-1935 (Smith, Soule and Mosby 1937). The results of the smaller coastal expeditions have been published by Jensen (1881 and 1889), Hammer (1883), Ryder (1889), Moltke (1896), Garde (1896) and Knudsen (1923). Finally, useful temperature observations were made in the years before 1940 in connection with fishery investigations by Hansen (1939 and 1940).

Temperature records used here were made at the stations shown on the map in figure 1. The records used had to be as closely as possible coincident in both locality and season. They are all from the coastal water of the west Green-

land current, and with two exceptions (figures 5 left, and 6 right) the seasonal range in any one figure does not exceed two weeks, and is usually less. Using this method of comparison, short-term fluctuations in the behaviour of the arctic and Atlantic water may be a disturbing factor. It is, however, the only method which the records allow, and as is shown below, the pattern of development of the present warm period in the west Greenland current, brought out by the present treatment, is consistent. Temperatures used in this paper are typical for the time and place at which they were recorded, and figures derived from abnormal areas (as for instance the Jakobshavn ice-fjord) have been avoided.

The situation in southwest Greenland is shown in figures 2 and 3 left. In

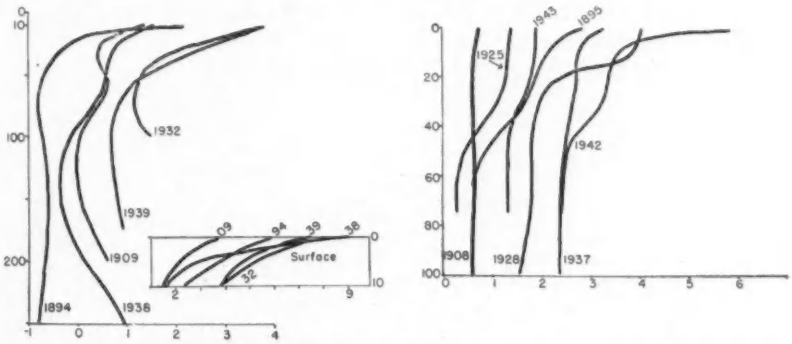

FIGURE 2. Left: Julianehaab district. 1894,—Mouth of Tasermiut fjord, August 16, 1894. Approximate position, 60°08′N., 45°11′W. (Moltke 1896). 1909, 1932, 1938 and 1939,—Lichtenaufjord; approximate position, 60°30′N., 45°33′W. August 22, 1909; August 15, 1932; August 12, 1938; August 18, 1939. (Hansen 1940).

Right: Godthaab district. 1895: Off Godthaab fjord, June 25, 1895; 63°57′N., 52°41′W. (Knudsen 1896). 1928: Off Godthaab fjord, June 18, 1928; 64°02′N., 52°19′W. (Riis-Carstensen 1936). 1925: Off Godthaab fjord, June 19, 1925; 64°11′N., 52°47′W. (Conseil Permanent 1926). 1908: Mouth of Godthaab fjord, June 20, 1908. "Tjalfe" expedition, quoted from Jensen (1939). 1937: Off Sardlok, just inside Godthaab fjord, June 26, 1937 (Jensen 1939). 1942: Mouth of Godthaab fjord, June 19, 1942. 1943: Mouth of Godthaab fjord, June 17, 1943. Ordinates, depth in metres; Abscissae, temperature centigrade.

figure 2 left, from the Julianehaab district in August, the gradual increase in temperature up to 1932 is apparent, followed by the cold year of 1938, reported by Hansen (1939), and the return to warm conditions in 1939. The very great difference in the deeper layers between the 1894 curve and the others is not due to an actual rise in temperature of this magnitude in the time interval, but to the fact that the 1894 record comes from inside the mouth of a "threshold" fjord (Tasermiut fjord), into which the passage of the warm underlying water outside is prevented by the presence of a threshold at the entrance.

Figures 2 right and 3 left (Godthaab, June and July-August) show a similar progression towards warmer conditions. The 1937 and 1942 curves in figure 2 right are almost coincident, and the colder spring of 1943 is shown in both figures.

It is interesting to note that the earliest temperatures, represented by the 1895 and 1885 curves in these figures, are not conspicuously lower than the 1928 temperatures, and higher, in figure 2 right, than the 1925 curve. An examination of the records of the end of the 19th century, and in particular the decade of 1880, shows that summer water-temperatures in this period tend to be a little higher than during the first 20 to 25 years of the present century. This is referred to again below. A most conspicuous example of this is illustrated in figure 3 right, where two series from the same station inside Godthaab fjord, about 27 miles north of the colony of Godthaab, are compared. The temperatures in the upper 100 metres recorded by Jensen (1889) in September 1885 are higher than those recorded by the present writer in 1944. (The 1944 station is not included in the figures given in table I, which contains only data from the mouth of the fjord.) Again, the "Fylla" expedition found comparatively warm water on the Fylla bank, off Godthaab, on July 1, 1884 (Wandel 1891), with temperatures of 1.9°C. at 38 metres, and 2.1°C. at 10 metres and at the surface.

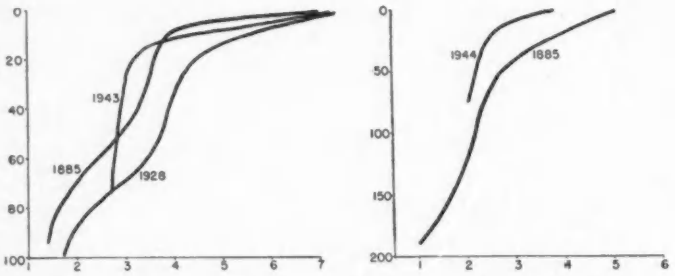

FIGURE 3. Left: Godthaab district. 1885: Mouth of Godthaab fjord, August 7, 1885 (Jensen 1889). 1928: Off Godthaab fjord, August 1, 1928; 64°01′N., 52°25′W. (Smith, Soule and Mosby 1937). 1943: Mouth of Godthaab fjord, July 24, 1943.

Right: Godthaab district. 1885: Inside Godthaab fjord, about 27 miles north of Godthaab colony, September 4, 1885 (Jensen 1889). 1944: Same position, September 8, 1944. Co-ordinates as in figure 2.

The drop in water temperatures in 1938, mentioned above, is shown also for the mouth of Godthaab fjord by Hansen (1939), and it is furthermore clear from a comparison of Hansen's figures for the middle 1930's, in the same report, with those given here in table I, that temperatures at this level of the coast have not risen appreciably since that time. This is also shown by the close agreement between the 1937 and 1942 curves in figure 2 right.

For the Sukkertoppen level, figure 4 left shows the 1889 conditions in the upper 100 metres to have been as warm as in 1924, in July-August; this is confirmed by examination of other stations of the "Fylla" expedition. Hansen's (1939) figures for the Sukkertoppen district show a temperature history during the 1930's similar to that of the Godthaab waters, with a distinct cooling in 1938. On the fishing-bank outside Holsteinsborg, further north, the "Fylla" found as warm water on July 18, 1884, as the "Godthaab" expedition found on July 2, 1928 (Riis-Carstensen 1936), with temperatures between 2 and 3°C. from

60 metres to the surface. In 1895, however, the "Ingolf" (Knudsen 1898) recorded lower temperatures in this area on July 10.

North of Holsteinsborg and the submarine ridge between Holsteinsborg and cape Walsingham in Baffin island, the hydrographic balance changes somewhat. The west Greenland current has weakened considerably, and the influence of the Baffin bay circulation is correspondingly greater. From the calculations of Smith, Soule and Mosby (1937), however, it is clear that Baffin bay derives its water in approximately equal quantities from the northwest and the southeast, so that changes in the west Greenland current continue to have considerable effect in Baffin bay. West of Godhavn, in southern Disko island, slightly higher temperatures between 50 and 75 metres are shown in figure 4 right for 1942 than for 1928, and a considerable difference between 1916 and 1928. The low temperatures around 25 metres in 1942 may be due to less solar heating or to the presence of icebergs. The rise in temperature apparent in 1928, compared to previous years, and the high temperatures recorded in 1884, are both well

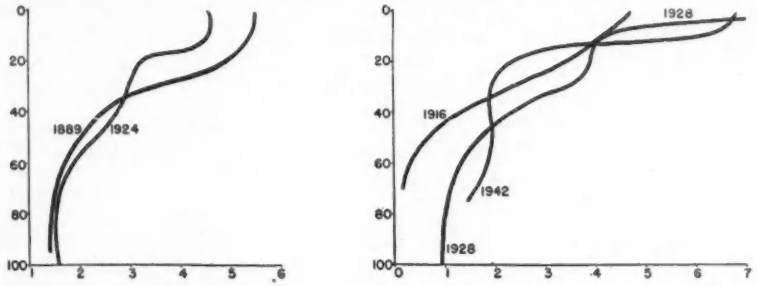

FIGURE 4. Left: Sukkertoppen district. 1889: Southwest of Sukkertoppen, July 29, 1889; 65°18′N., 53°21′W. (Wandel 1891). 1924: South of Sukkertoppen, August 6, 1924; 64°53′N., 52°55′W. (Martens 1929).

Right: Disko bay area. 1916: West of Godhavn, August 1, 1916; 69°15′N., 54°00′W. (Knudsen 1923). 1928: Southwest of Godhavn, August 7, 1928; 69°09′N., 53°32′W. (Smith, Soule and Mosby 1937). 1942: Two miles west of Godhavn, July 31, 1942. Co-ordinates as in figure 2.

illustrated in figure 5 left, for the middle of Disko bay. The difference in the deeper water is particularly remarkable. The seasonal time interval between the 1908 curve and the 1928 curve in this figure is as much as three weeks; the 1908 curve may thus be a little too far to the left, though probably not significantly so. The similarity between the 1884 and 1928 curves, evident in figure 5 left, is again shown in figure 5 right. Here again is demonstration of comparatively warm water conditions in the 1880's, corroborated by the fact that temperatures as high as 2°C. were recorded by Hammer (1883) outside the Jakobshavn icefjord from 40 to 100 metres depth in November 1883.

Figure 6 left compares 1928 and 1943 temperatures from the eastern side of the Vaigat, in September. The curves are in fairly close agreement, and have the wavy form often found in the vicinity of any considerable quantity of bergice. The Vaigat, at this time of year, is the main outlet for icebergs from the Jakobshavn ice-fjord.

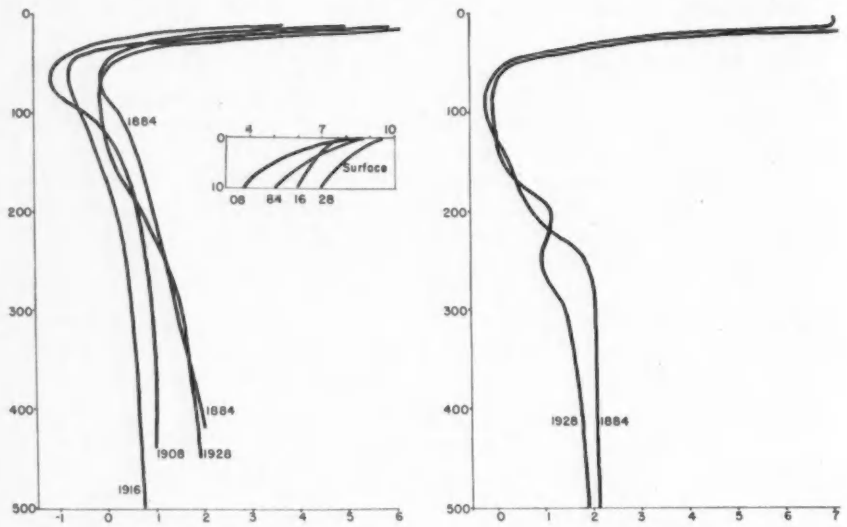

FIGURE 5. Left: Disko bay area; middle of bay. 1884: July 23, 1884; 69°17′N., 52°15′W. (Wandel 1891). 1908: July 16, 1908; 69°12′N., 52°08′W. (Knudsen 1923). 1916: July 22, 1916; 69°13′N., 52°20′W. (Knudsen 1923). 1928: August 8, 1928; 69°12′N., 52°13′W. (Smith, Soule and Mosby 1937).

Right: 1884: East of Godhavn, July 23, 1884; 69°14′N., 52°54′W. (Wandel 1891). 1928: East of Godhavn, August 8, 1928; 69°12′N., 52°49′W. (Smith, Soule and Mosby 1937). Co-ordinates as in figure 2.

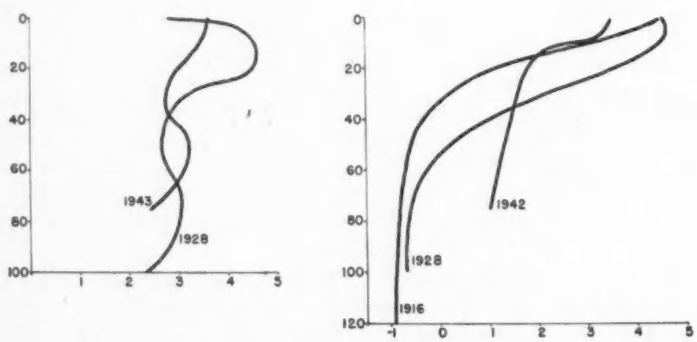

FIGURE 6. Left: The Vaigat. 1928: September 6, 1928; 70°07.5′N., 52°33′W. (Riis-Carstensen 1936). 1943: September 15, 1943; approximate position, 70°00′N., 52°20′W.

Right: Upernavik district. 1916: South of Upernavik, August 3, 1916; 72°30′N., 56°12′W. (Knudsen 1923). 1928: SSW. of Upernavik, July 21, 1928; 72°37′N., 56°31′W. (Riis-Carstensen 1936). 1942: Four miles south of Upernavik, August 30, 1942; approximate position, 72°43′N., 56°11′W. Co-ordinates as in figure 2.

The temperature curves in figure 6 right are separated by so large a time interval that they are not properly comparable. They represent, however, the only material available from the vicinity of Upernavik, with the exception of temperatures from close to the inland ice in the same latitude as Upernavik, taken by Ryder in August 1886 (Ryder 1889). Ryder's figures have not been included in figure 6 right, as the distance between his stations and those shown in the figure is some 35 miles, and the conditions are unlike. They show bottom temperatures of 2.0, 2.5 and 2.7°C. in depths of 114, 137 and 146 metres respectively. These are remarkably high temperatures, and can only be due to Atlantic influence. They are further evidence of warmer water in the 1880's, in summer. In figure 6 right, the 1928 temperatures are a little higher than those of 1916, and were taken two weeks earlier in the season. They are thus evidence that the increasing temperatures in these years, found further south, reached as far north as Upernavik. The seasonal interval between the 1928 and 1942 curves is 40 days, during which time the temperatures in 1928 might be expected to have increased somewhat. All that can be inferred with certainty, therefore, from the 1942 figures is that Atlantic influence is clearly discernible in August at Upernavik. A glance at temperatures in August and September 1940, taken at River Clyde and at Lake Harbour in Baffin island (Dunbar 1942), is sufficient to bring this point out. The contrast between the arctic water of Baffin island in 1940, and of Hudson strait in 1930 (Hachey 1931) on the one hand, and the mixed arctic and Atlantic water of Upernavik on the other, is very striking.

CONCLUSION

Examination of temperature records from west Greenland since 1880, shown here by representative temperature curves, has traced the development of the present warm period in the west Greenland current, and has further demonstrated that summer temperatures during the 1880's were somewhat higher than in the ensuing years up to about 1920. This is an unexpected result, the more so since the ice records compiled by Speerschneider (1931) show that during the decade of 1880 the transport of ice up the coast was above normal. Speerschneider himself points out, however, that the amount of floe-ice in west Greenland is not necessarily a function of the quantity of arctic water in the west Greenland current, but is largely dependent on the agency of winds during the early part of the year. The fact of high water temperatures in the 1880's tends to colour our opinion as to the permanence of the present warm period, for there are already known to have been warm periods during the decades of 1820 and 1840 (Jensen 1939); the present period, although considerably longer than earlier warm periods, would seem to take on the significance only of another peak in the oscillation.

Records from the mouth of Godthaab fjord in 1942-1944 show that the influence of the Atlantic component of the west Greenland current is greatest from July to September. Comparison of these temperatures for 1942-1944 with Hansen's records for the 1930's (Hansen 1939, Jensen 1939), shows that there has been no rise in water temperatures since the middle 1930's in that region. There are indeed indications, as described above, of a weakening of Atlantic influence between 1942 and 1944.

A most important economic result of the warming of the west Greenland current has been the development of a cod fishery along the whole coast, from cape Farewell to Umanak. The output of this fishery has increased during the war years, despite evidence of Atlantic weakening, but the increase is more probably due to rise in population and to sustained efforts to increase production by various means, than to any hydrographic agency.

Parallel with the lower water temperatures in spring and fall recorded at Godthaab, there have been changes in the winter ice conditions in west Greenland in the past few years. The ships' harbour at Godthaab, for instance, was frozen over completely in the winter of 1943-1944, a very rare occurrence, and again in 1944-1945, in the month of February. In Disko bay, it was possible to sledge from Jakobshavn over to Skansen in south Disko island in February 1945, for the first time in 23 years (Grønlandsposten 1945). It is also notable that in August 1940 Godthaab was blocked to navigation by floe-ice ("Storis") for the first time since 1898.

To sum up: There appears to have been a short period of warmer water in west Greenland in the decade following 1880, followed by a colder period represented by the records for 1908, 1909 and 1916. By 1928 the conditions were considerably warmer, and there is reason to believe that the peak of the present warm period was reached in the 1930's. The Atlantic influence, however, was clearly evident in latitude 72°N. in the summer of 1942. The cold year of 1938, and the signs of a retreat of the Atlantic water at Godthaab during 1942-1944, suggest that the cycle may be falling back to colder conditions. Added weight is lent to this possibility by the increased winter ice of very recent years. This interpretation is in agreement with the meteorological study of Scherhag (1937), referred to earlier in this paper, in which it is suggested that the recent warming of the arctic and subarctic regions from Greenland to Siberia is one manifestation of a large-scale climatic cycle of some 225 years' period, which in the 1930's seemed to have reached its maximum. Inside this major cycle, there have been minor oscillations in west Greenland, at least since 1820, of which the present one is the greatest.

ACKNOWLEDGEMENTS

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Polychaeta from the Bay of Fundy 1911-1912

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ABSTRACT

Records are given of eight polychaetous annelids new to the North American coast, and eleven new to the bay of Fundy.

Under the direction of Dr. A. G. Huntsman in the summers of 1911 and 1912 a collection was made of the polychaetous Annelida from the Biological Station at St. Andrews, New Brunswick, Canada, and in the neighbouring waters. These were in part worked over during the winter of 1911-1912 and the results embodied in a thesis for M.A. which was not published. It has been thought advisable to record the new findings. Since the collection was, unfortunately, almost completely destroyed during my absence in the first great war, it is only possible to extract from the thesis which covered the 1911 collection and from the field notes for both 1911 and 1912 what seems significantly new and dependable. The identifications, although not checked over by any other person and not now capable of review owing to the loss of the specimens, were carefully and conservatively carried out and should stand. The following species in that collection show extensions of their distribution as previously known.

1. **Ampharete goesi**, Malmgren.

Dredged in 14 fathoms (1 fath. = ca. 1.8 m.) in sandy mud near Treat island, also in 15 fathoms near Dochet island, 1911.

Originally described by Malmgren (1866) from Spitzbergen. Identified from his description. Not previously known from the western Atlantic.

2. **Eteone arctica**, Malmgren.

In trawl off Joes point, St. Andrews, 1912.

Originally described by Malmgren (1868) from Spitzbergen. Identified from his description. McIntosh described it from Spitzbergen, Greenland, Southport sands, Siberia and Behring strait. New to the American coast south of Greenland.

3. **Eulalia problema**, Malmgren.

Off Joes point, St. Andrews, 6-7 fathoms in sand and mud, 1912.

Originally described by Malmgren (1866) from west of Greenland. Identified from Malmgren's description. Not previously recorded from Canadian waters.

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4. Eulalia viridis, O. F. Müller.

Found on a sculpin at Carson's weir, St. Andrews, 1912.

Originally described (Müller 1776) as *Nereis viridis*. Identified from McIntosh (1908). A new record extending the Greenland record westward and south. Also reported from Madeira, the Canaries, South Africa and Behring sea.

5. Eumida sanguinea, Oersted.

Found on weir stakes, Bay of Fundy, 1912.

Described originally by Oersted (1843). Identified from McIntosh's (1908) description of forms around the British shores and in the Baltic. Extends the range westward to North America.

6. Samytha sexcirrata, Sars.

Dredged in 23 fathoms in mud in Passamaquoddy bay, 1911.

Originally described by Sars (1856). Identified from Malmgren (1866 and 1868). Reported by Whiteaves at great depth, 220 fathoms, between Anticosti and the south shore. Verrill reports it from New England and the Atlantic coast. Also in the Arctic and Antarctic seas. New to the bay of Fundy.

7. Euchone rubrocincta, Sars.

Bay of Fundy, 1911.

Originally described by Sars (1862). Found by Moore (1910) at Egg harbour, Labrador, and by Verrill in northern New England. Identified from Malmgren (1866). New to the bay of Fundy. Connects north and south distributions.

8. Scione simplex, Verrill.

In the littoral region on eel grass (*Laminaria*) at Grand Harbour, Grand Manan, 1911.

Identified from Verrill's description (1874). Found at low water to 6 fathoms from New Haven to Vineyard sound. This report extends its range to the north.

9. Potamilla neglecta, Sars.

In 60 fathoms off Scott head, Campobello, 1911.

Identified from Malmgren (1866). Reported by Whiteaves (1901) in 45 fathoms at La Have bank, Nova Scotia, and by Smith and Harger (1874) as abundant in 60 fathoms in the region of the St. Georges banks. New to the bay of Fundy.

10. **Potamilla torelli,** Malmgren.
St. Andrews, New Brunswick, 1911.
Identified from Malmgren's original description (1866) of specimens from Iceland. Reported found by the Challenger expedition south of Halifax by Whiteaves (1901). New to the bay of Fundy.

11. **Sabella crassicornis,** Sars.
Bay of Fundy, 1911.
Identified from Malmgren (1866). Recorded by Moore (1910) off Sable island, Nova Scotia. New to the bay of Fundy.

12. **Protula americana,** McIntosh.
North end of Grand Manan in 29 fathoms, 1911.
Identified from McIntosh (1885) in the report of the Challenger Expedition as dredged south of Halifax. New to the bay of Fundy.

13. **Paraxiothea catenata,** Malmgren.
In 15 fathoms in Passamaquoddy bay, 1911.
Reported by Whiteaves from the Bradelle bank. Identified from Malmgren (1866). New to the bay of Fundy.

14. **Nereis fucata,** Savigny.
Carter's weir, St. Andrews, 1912.
Identified from McIntosh (1910). Dredged by Verrill (1874) at Watch Hill, Rhode Island. New to the bay of Fundy.

15. **Phyllodoce maculata,** Linnaeus.
In 10 fathoms off Brandy cove, St. Andrews, 1912.
Identified from McIntosh (1908). New to North America.

16. **Alentia (Halosydna) gelatinosa,** Sars.
St. Andrews, beneath rocks, 1912.
Identified from Malmgren (1866). New to North America.

17. **Dasylepis asperrima,** Sars (1873).
St. Andrews, 1912.
Identified from Malmgren (1868). New to North America.

18. **Scalibregma inflatum,** H. Rathke.
At St. Andrews in sand. Also at Woodwards cove, Grand Manan, 1911.
Identified from McIntosh (1885). Whiteaves reports it from the gulf of St. Lawrence. New to the bay of Fundy.

19. **Autolytus longisetosus,** Agassiz.
10 fathoms off Joes point, St. Andrews, 1912.
Identified from Verrill (1882). New to the bay of Fundy.

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Heat Stroke in Canadian Maritime Stream Fishes

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ABSTRACT

On June 13, 1942, after a warm period, *Alosa*, *Catostomus*, *Pomolobus*, *Salmo*, *Salvelinus* and other fishes died in parts of the Petitcodiac, Shubenacadie, French, Waugh and John rivers. The streams affected were moderately rapid, broad, shallow and long, with spring sources. They were low from slight rainfall and in districts with relatively cloudless skies during the period. These streams showed daily minimal and maximal temperatures rising steadily (to 88½° F. or 31.4° C.) under warm moist air conditions, which evidently reduced radiation at night more than insolation during the day.

Heat stroke in fishes has long been known experimentally, John Davy having described it as early as 1862. That it occurs in nature had apparently not been demonstrated until our observations were made in 1939 (Huntsman 1942). It may be a rare phenomenon, as is perhaps to be expected seeing that the high specific heat of the water in which fishes live tends to prevent their being exposed to directly lethal high temperatures. The summer of 1942 provided a rather different picture of heat stroke in fishes from that of 1939.

Data have been freely furnished by the Meteorological Service as well as by officers of the Department of Fisheries and members of the staff of the Fisheries Research Board.

OBSERVATIONS ON FISHES

Petitcodiac River, N.B.

Dr. D. G. Wilder (unpub.) operated traps for descending salmon smolts on the Petitcodiac and Pollett rivers short distances above their junction near River Glade, N.B. (fig. 1) from May 7 to June 17. With high temperatures culminating on June 13, many shad (*Alosa sapidissima*) were seen dead in the Petitcodiac river and records were made of 2,517 found dead between June 12 and June 17, the great majority on June 13. These were large, spawning shad, in the river from the sea at that time of year. The deaths occurred chiefly in a five-mile (1 mile = 1.6 km.) stretch of the river at the head of tide (upwards from Boundary creek), that is, in the lowest part free from sea water influence with existing neap tides. Young salmon were reported as dying in large numbers

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in certain tributary streams on June 14,—in the North river at Fawcett Hill and in the Coverdale river about two miles from Salisbury. Dead parr and smolts were found in and near the traps from June 12 to 16. Other fish found dead during this period but in smaller numbers were suckers (*Catostomus commersonii*), gaspereaux (*Pomolobus pseudoharengus*), trout (*Salvelinus fontinalis*), eels (*Anguilla chrysypa*), and two kinds of minnows (*Couesius plumbeus* and *Semotilus atromaculatus*). Salmon parr, suckers and *Couesius* entered the Pollett trap in large numbers during this period, as if stimulated by the heat. The Petitcodiac trap was not operated fully enough to show this effect well.

The Petitcodiac proper was examined in August of 1942 at a number of points along its course, and its fish population compared with those of the tributary spring-fed brooks, whose water would not have reached such high temperatures. Without giving the details (Huntsman unpub.) it was concluded that in comparison with those of the tributaries and with what it itself was when examined on July 29, 1937, the fish population of the Petitcodiac had been practically wiped out except in some parts with deep water. Repopulation seems to have been a very gradual process. The relatively barren condition reached in 1942 cannot be attributed solely to the high temperatures of early June. The water remained exceptionally low until late in the autumn and may have become very warm after the period of observation. Also both low water and high temperature short of the lethal may have made the fish more readily available to their enemies.

That the Petitcodiac river and its tributary the Pollett are somewhat prone to have fish die from heat stroke is evidenced by the report that salmon are sometimes to be picked up, by gulls and men, when stranded on the flats or in the tidal pools of the Petitcodiac estuary. At about 5 p.m. on September 2, 1942, some of these tidal pools were to the bottom as warm as 83° F. (28.3° C). Mr. A. E. Power, who lives at the mouth of the Pollett river, has reported that in August of 1928, adult salmon died in that river for at least a mile up from the mouth, the weather being very dry and warm. Inspector Bruce Barnes of Salisbury has stated that presumably at that time many salmon died in the Petitcodiac below the mouth of the Pollett, 150 dead fish being counted in a two-mile stretch above the head of tide. The Meteorological Records show that July and August of 1928 at Moncton were dry and that the maximal air temperatures were above 80° daily from August 13 to 19, being 92 or higher on three successive days, with minimal temperatures from 58 to 69° F., which figures are higher than those recorded at Moncton for June, 1942.

Northern N.S. Rivers

Inspector G. M. Adamson of Pictou investigated on June 13 reports of fish dying in rivers to the westward that empty into Northumberland strait. Young salmon, trout, suckers, and gaspereaux were found dead in the lower part of French river (fig. 1) with a water temperature of 88½° F. (31.4° C.) in rapids. Some dead fish were reported for the lower part of Waugh river, although none

were found. The local guardian reported gaspereaux, young salmon, suckers and eels as dying in the John river in a mile-long stretch just above the head of tide.

I examined the French river in late August of 1942 and found yearling salmon very few in number (compared with observations in 1940) within a mile upward from the head of tide, where young salmon were found dead on June 12 and 13. Underyearling salmon, which had presumably emerged from the redds about the first of July, were quite numerous. Three miles up from tidal waters

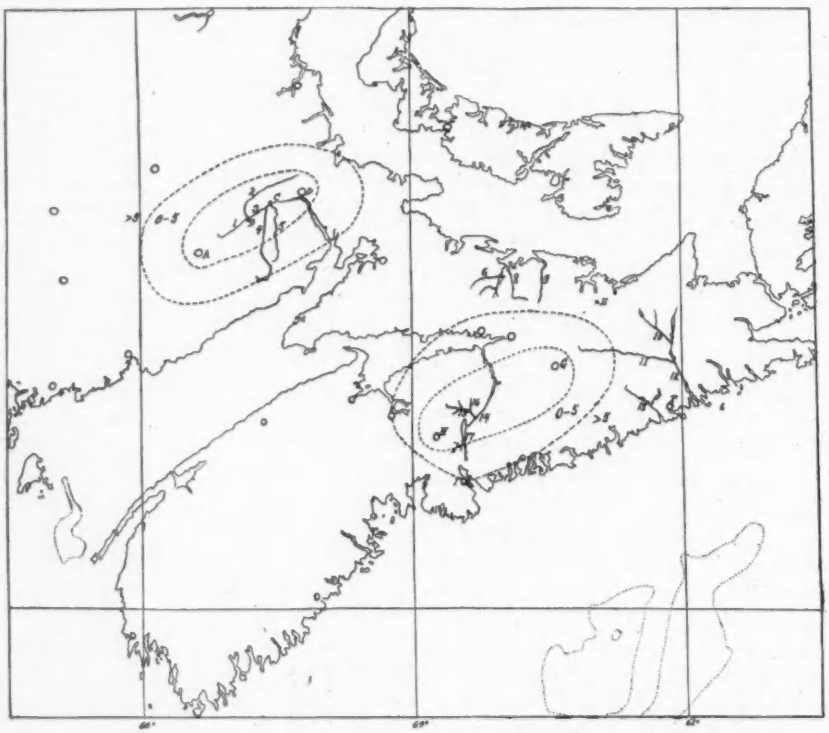

FIGURE 1. Maritime provinces, showing locations of rivers in which fish died and the distribution of clouds on June 12, 1942, as reported by observers of the Meteorological Service (circles indicate observation points and interrupted lines show roughly the limits of the cloudless and half-clouded areas). Rivers and brooks are numbered, viz.: 1—Anagance, 2—North, 3—Petitcodiac, 4—Pollett, 5—Coverdale, 6—Donaldson, 7—French, 8—Waugh, 9—John, 10—East, 11—West, 12—St. Mary, 13—Moser, 14—Shubenacadie, 15—Nine-Mile, and 16—Grant, while 17 is Grand lake. Places are lettered, viz.: A—Sussex, B—Petitcodiac, C—Salisbury, D—Moncton, E—Stellarton, F—Ecum Secum, G—Upper Stewiacke, H—Mt. Uniacke, and I—Halifax.

there was a similar condition, with a similar report of dead young salmon in June, but two miles farther up where there was local knowledge of only trout

being found dead in June there was an abundance of both yearling and under-yearling salmon.

A similar situation was found in Donaldson brook, a tributary of French river, yearling salmon occurring in fair abundance except in the lower, broad and shallow part, which was practically devoid of fish.

Shubenacadie River, N.S.

Inspector E. M. Arnold had reported in June that shad were dying in Nine-Mile river, a tributary of the Shubenacadie (fig. 1). From 150 to 200 shad, all about 3 lb. (1⅓ kg.) in weight, were found dead on June 13 in the lower half-mile of the Nine-Mile, but not elsewhere, although live shad were present farther up this stream as well as in the Shubenacadie river itself, which arises from Grand lake. Also trout were reported as dying a mile or so up the Nine-Mile river. Examination in early September of 1942 showed a very barren condition for at least five miles up this river from its mouth, although its tributary, Grant brook, showed a good population of fish, including yearling salmon parr, a short distance above its mouth.

Also, in the Shubenacadie river itself, five salmon from about 6 to 25 lb. in weight had been found dead both above and below the head of tide in late August and early September. As the river water had been very low, and as the fish were without signs of injury and in good condition at death, it seems probable that they were killed by heat stroke, the dead fish being related to the head of tide where the warmest water occurs. No temperature records were available.

HYDROLOGICAL CONDITIONS

Locality

Lack of precise data prevents positive statements as to the difference in conditions in the water between the places with and without mortality of fish.

In the Petitcodiac system, death of fish was observed or reported in the lower parts of the Petitcodiac, Pollett, Coverdale and North rivers, but not in the upper parts of these rivers nor in any parts of the Anagance river or of any of the many brooks of the system. The places where deaths occurred are those that limited observations have shown to reach the highest temperatures. Their features are (1) steady and moderate declivity, giving heavy currents during high water and almost continuous rapids with but slight flow during low water, (2) evenness of bed of stream through the filling up of holes with material carried down, (3) breadth and openness as a result of the clearing action of the freshets, and (4) long travel of waters under these conditions, that is, a considerable length for this part of the river. The contrast between one of the streams where the fish died and a neighbouring short tributary with no deaths and a heavy population of fish was striking.

The conditions where deaths occurred in the French, Waugh, John and Nine-Mile rivers were similar to those in the Petitcodiac system.

TIME

It will be seen (fig. 2) that in both the Petitcodiac and the Pollett rivers at the trap the great mortality of June 13 was at the end of a period during which the minimal and maximal temperatures rose from day to day, beginning on the 6th, with a slight recession on the 9th. Minimal temperatures reached heights of 74½ and 77¾, (23.6 and 25.4) and maximal temperatures heights of 88 and 88½° F.(31.1 and 31.4° C.) respectively in the waters of the two rivers. These seem sufficient to explain the mortality. In addition to being the outcome of a combination of high temperature and time, the mortality was also the result of low acclimation; this period of rapidly mounting temperature came in early June when the fishes had not yet been acclimated to the very high temperatures. The highest temperatures previously recorded that season were 73⅓° on May 25 in the Petitcodiac and 73⅔ and 72⅔° on June 2 in the Petitcodiac and Pollett respectively. The fish were less well acclimated in the Pollett.

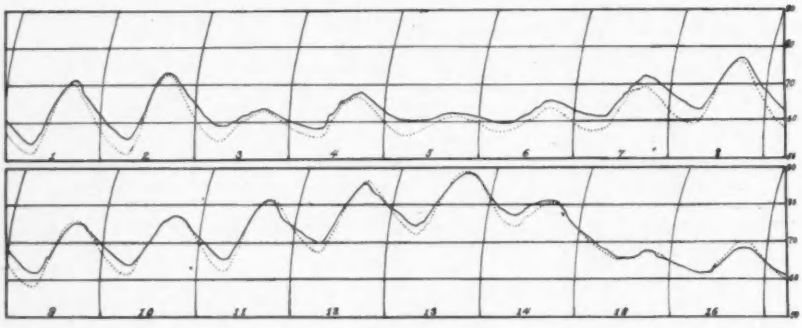

FIGURE 2. Courses of temperature (°F.) in the Petitcodiac (————), and Pollett (.....) rivers above their junction, from June 1 to 6, 1942, as recorded by Dr. D. G. Wilder.

Previously (Huntsman 1942), mortality by heat stroke was reported for July and August in certain Nova Scotia rivers. It may, therefore, occur in any of the three summer months, during which water levels are apt to be low and insolation is great.

METEOROLOGICAL CONDITIONS

RAINFALL

The rivers were low, but not exceptionally so. For the Petitcodiac river, rainfall was 1.34 in. (1 in. =2.54 cm.) in May and 1.40 in. in June at Petitcodiac village, where the average rainfall is 2½ to 3½ inches per month. For the Shubenacadie river, rainfall was 2.61 in. in May and 1.76 in. in June at Mount Uniacke, where the average is about 3½ inches per month. For the French, Tatamagouche and John rivers, rainfall was 1.53 in. in May and 0.49 in. in June at Stellarton, the nearest recording station.

Moisture in the Air

Since, as in 1939, the development of the high temperature in the water showed day after day no great gain of heat during the day but less loss at night than gain during the day, the moisture content (dew point) of the air was studied to determine whether "the warmer moist air resulting from the final movement of air from west and southwest was doubtless a factor in reducing the loss of heat by radiation" (Huntsman 1942). In 1942 as in 1939, the high water temperatures developed when the dew-point of the air as well as both minimal and maximal temperatures were rising to high levels. In the Petitcodiac region (Sussex and Moncton), morning dew point, which had been as low as 32° at the beginning of the month, rose from about 50° on June 8 to nearly 70° on June 13, while minimal temperatures rose correspondingly and maximal temperatures approximated or even surpassed 90° F. (32.2° C.). This condition was quite general over the Maritimes, and was doubtless the result of movement of air from the west and southwest.

Sunshine

Since clouds greatly reduce heating of the water by insolation, high water temperatures would be reached only where there was relative freedom from clouds during the period (June 6 to 13) when the streams developed lethally high temperatures. Only scattered records are available, but these show that during the period indicated the district in which the Petitcodiac river is (observations at Sussex and Moncton, N.B.) and that in which the Shubenacadie river is (observations at Mt. Uniacke and Upper Stewiacke, N.S.) were relatively free from clouds. At all four places reports indicated little or no clouds, from at least June 9 to 12 inclusive. There are no records to show conditions in the district of the French and neighbouring rivers, but they were doubtless similar.

To illustrate the local character of this cloudless condition: On June 12, the sky was cloudless all day at the four places mentioned, while at all other observation points (fig. 1) there was more or less cloud, and in some places the sky was fully clouded all day.

The Moser river, about 100 miles along the coast northeast from Halifax and near Ecum Secum, failed to show very high temperatures in June of 1942 although it had temperatures lethal for salmon both in 1937 and 1939. The continuous record made of its temperature in 1942 showed no temperature above 80° (26.7 ° C.) in June and temperatures rarely above 70° F. until near the end of the month. It may be concluded that the cloudiness which prevailed in the district (fully clouded at Ecum Secum from June 9 to 16) prevented development in the Moser river of the high temperatures experienced in certain rivers situated in areas unclouded during the second week of June.

It is concluded that meteorologically the mortalities of fish in June of 1942 were restricted to districts with relatively clear sky during a period of some days in which conditions otherwise were suitable for the development of high temperatures.

DISCUSSION

It is extraordinary that the shad should be found to die from heat stroke at spawning time in streams almost at the northern limit of their range, where the streams are on the verge of not being warm enough for spawning. Leim (1924) showed that, in one of these streams, the Shubenacadie, spawning was frequently checked by the temperature of the water dropping below 12° C. (53½° F.). The shad spawn in the lower parts of the streams, which become warmest.

Heat stroke in fishes seems to occur not infrequently in Nova Scotia and New Brunswick. It is surprising to find it in a region which is surrounded on nearly every side by water—the Atlantic, the bay of Fundy and the gulf of St. Lawrence—and which has relatively cool summers. Lack of report of this phenomenon elsewhere on the continent may or may not be significant of any difference. As yet, we lack detailed records of water temperature to show whether or not the high temperatures (approaching 90° (32.2° C.) in 1937, 1939 and 1942 particularly) sometimes reached by certain Maritime streams are at all peculiar to the region.

The lethal temperatures in August of 1939 were in a lake-fed stream, Moser river. The deaths of salmon in July of 1937 occurred not only in the Moser river, but also in the St. Mary river and in the latter mainly in a pool where the lake-fed East river joins the spring-fed West river, and the mortality seemed to be clearly related to the warm water of the former. In June of 1942, however, the fish died in every case in spring-fed streams. No deaths were reported in the Shubenacadie river itself, which arises from Grand lake, but only in its spring-fed tributary, the Nine-Mile river. It is conceivable that lakes may aid in having their discharging streams reach a high temperature by cooling off less at night. If deep and therefore slowly warmed, as Grand lake is, they will not be thus affected, particularly during the early part of the season.

The deaths in 1942 occurred, it is true, in spring-fed streams, but only in long streams and in their lower parts, most of whose water had been exposed in a broad, shallow bed to the sun for many miles. Also the high temperatures were reached only when these streams were quite low and therefore flowing slowly.

The atmospheric background was in each case warm, muggy weather, resulting from movement of air coastwise from the southwest, for a period of about a week. The localities, in which the high temperatures were reached in 1942, were those which, as far as records are available, had clear sky for that period at least during the day. How restricted such a condition was in 1937 and 1939 has not been studied.

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Restocking Depleted Sockeye Salmon Areas by Transfer of Eggs

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ABSTRACT

Eggs from Cultus lake, a lower Fraser river tributary, and from Adams river, in the Shuswap lake region, were transferred to Eagle river, a formerly important sockeye salmon stream at the head of Shuswap lake. The resulting fingerlings were marked, prior to liberation into Eagle river, by removal of certain fins for subsequent identification. Recovery of surviving adults—few in the commercial fishery, few, if any, in the original native spawning areas, none at Eagle river from the Cultus lake egg transfers and very few from the Adams river shipments—indicates that restoration of depleted sockeye areas cannot be achieved merely by introducing eggs from any outside well-populated areas.

For several years prior to 1928 the Federal Department of Fisheries had endeavoured to restore the once highly-productive but, then, severely-diminished stocks of sockeye salmon in the Shuswap lake area (fig. 1) by transferring eggs from well-populated regions of the lower Fraser. Egg planting, i.e., the planting of the eggs in the natural gravel bars of the tributary rivers (Harrison 1923) was the method used and Eagle river (fig. 1) was the stream chiefly utilized. Plantings made from 1922 to 1926 were as follows:

Year	Number of eggs planted	Origin of eggs
1922	2,300,000	Cultus lake
1923	1,176,000	Cultus lake
1924	2,000,000	Cultus lake
1925	2,000,000	Birkenhead system
1926	2,700,000	Birkenhead system

Subsequent observations indicated, however, that the runs to the planted areas were not improving to any appreciable extent. The sockeye eggs transferred to Eagle river came from lower Fraser tributaries, chiefly Cultus lake and the Birkenhead river (fig. 1). Since the sockeyes frequenting these spawning grounds have a much shorter and less hazardous migration to undertake in order to reach their destinations and, in fact, bear characteristics of colour and size that suggest different strains from those penetrating to the upper river areas, the possibility existed that these lower Fraser fish, when reared in upper Fraser waters, i.e., above the Fraser canyon, would not physically be able to return to these more distant streams. They might, then, either (1) reach the ocean and on their return from the sea be detected in the fishery, (2) perish in

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the Fraser in an effort to achieve their goal; (3) return to their parental spawning areas; (4) seek suitable spawning beds in intermediately located streams; or (5) actually return to the planted area.

With a view to obtaining information on (1), (3) and (5) the Fisheries Research Board of Canada commenced, in 1929, a series of experiments on Eagle river, utilizing eggs from Cultus lake, a lower Fraser river tributary, in two years, 1929 and 1932, and eggs from Adams river, in the Shuswap lake system, in 1930 and 1931. In order to be able to trace the transplanted fish

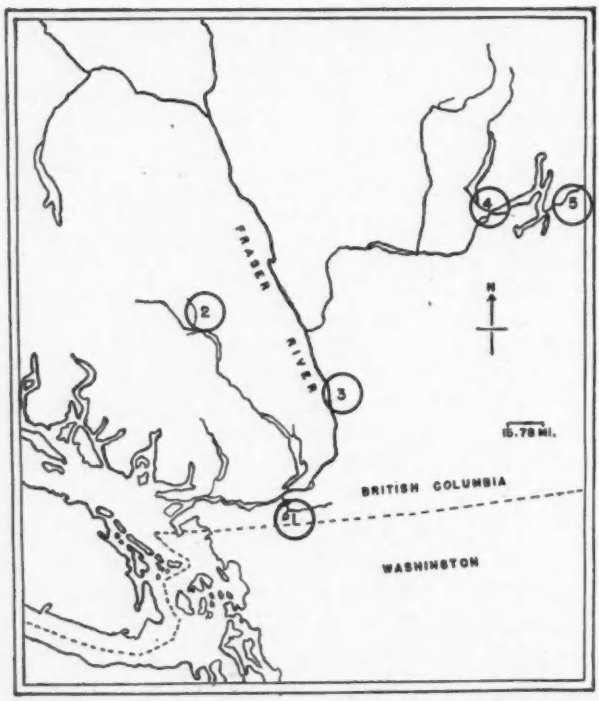

FIGURE 1. Sketch map of southwestern British Columbia showing the relative positions of the commercial fishing grounds out from the mouth of the Fraser river, Cultus lake (1), Birkenhead river (2), Hells Gate canyon (3), which is taken arbitrarily as the dividing line between lower and upper Fraser river areas, and the Adams (4) and Eagle (5) rivers.

after liberation and when returning from the sea as adults, it was necessary to rear them to a size at which they could be distinctively marked—by removal of certain fins—and then set them free in Eagle river.

Three large retaining ponds were constructed in the early spring of 1929 at the deserted townsite of Taft on Eagle river. The eggs from Cultus lake were held at the Cultus or Harrison lake hatcheries during the winter and shipped to Taft in the spring in the "eyed" stage, but the Adams river eggs

were transferred immediately to Taft, incubated to the "eyed" stage in stacked trays in a partially heated room and then moved to the hatching troughs.

In table I are given the records of fingerlings liberated in each of the four years and the marks which were used. The marked fish were transferred from the ponds directly to the lower reaches of adjacent Crazy creek from which they dropped gradually into Eagle river.

TABLE I. Records and returns of sockeye fingerling liberations from Taft rearing ponds into Eagle river, 1929-1933.

Year	1929-1932		1930-1933		1931-1934		1932-1935	
Origin of eggs	Cultus lake		Adams river		Adams river		Cultus lake	
Number of fingerlings marked	123,550		271,632		287,759		293,751	
Period of marking	Oct. 17-29		Oct. 17-31		Oct. 6-Nov. 9		Sept. 28-Oct. 19	
Mark used	Left pelvic and adipose fins		Right pelvic and adipose		Left pelvic and adipose		Right pelvic and adipose	
Returns from	Male	Female	Male	Female	Male	Female	Male	Female
Fishing areas	8	4	57*	47**	23	20	?	?
Cultus lake	?	?					0	0
Adams river					0	0		
Eagle river			3***		6	1		
	(13)****	(7)	(11)	(2)	(40)	(9)	(12)	(5)

*1 3_2 taken in 1932.

**1 5_2 taken in 1934.

***includes 1 3_2 male recovered in 1932.

****figures in brackets indicate the number of unmarked sockeye taken at the counting fence in each season.

In all cases the fish were released in good condition and appeared to assume quite readily their natural habits when liberated into the shallow water of Crazy creek. Observations subsequently made each year at various points along Eagle river below Taft indicated that the fish were proceeding down to Shuswap lake. No evidences of heavy mortality in the river were found.

RECOVERY OF RETURNING ADULTS

The return of the marked adults from the Eagle river experiments of 1929, 1930 and 1931 coincided with the return to the Fraser river and to Cultus lake of sockeye from extensive markings at Cultus lake (Foerster 1936b). Facilities were therefore available for recovery of the Eagle river marked fish not only in the fishing areas where special examination of sockeye landed at the canneries was undertaken in 1932, 1933 and 1934 but also from the counting weir at Cultus lake, should any return there—their original spawning area—in 1932 and 1935. No campaign to recover marked individuals in the fishing areas was undertaken in 1935 but it was anticipated that any fisherman noting marked sockeye among his catches would report them.

At Eagle river itself a counting fence was constructed during the summer of 1932 in the lower section of the river and all ascending fish were trapped and closely examined during the 1932, 1933 and 1934 seasons. In 1935, due to

lack of adequate funds and the likelihood of but few returns, if any, it was decided not to operate the fence but to rely solely on a careful stream survey.

In table I are given the records of adult sockeye recovered in the fishing areas and at Eagle river, bearing marks similar to those used at Eagle river during the four experiments. As intimated above, the counting fence at Eagle river was not operated in the fall of 1935 but a careful survey of the river was made during the season by the resident Fishery Guardian, Mr. G. Mould. At the end of the season he reported as follows:

"The approximate number (of sockeye) observed on spawning beds did not exceed thirty-five to forty fish . . . . I carefully examined and counted about 27 sockeye actually spawning on beds and afterward made a check-up on these by examining 12 male and 5 female sockeye dead and dying on the banks of the river but in no instance did I find any marked specimens."

DISCUSSION

(a) Capture in the Fishing Areas

During the *1932* fishing season the 8 male and 4 female sockeye, recovered with left pelvic and adipose fins removed, corresponded otherwise in size and age with the Eagle river marking of 1929. Close inspection of the scars of the missing fins was made and it was reasonably established that the marks found were not due to accidental mutilation or non-development of the fins.

For the recoveries in *1933* the distinction between genuine Eagle river marked fish (adipose and right pelvic fins missing) and poorly or incorrectly marked Cultus lake individuals (adipose and both pelvics off) was not so clear. Of all the 9,245 marked salmon observed in the sockeye fishery with at least two fins lacking the records indicate that 9,107 had the adipose and both pelvic fins off (Cultus lake four year olds), 36 had the two pelvic fins only removed (Cultus lake five year olds), 54 had the adipose and left pelvic fins lacking and 102 had the adipose and right pelvic fins missing.

Had it not been for the occurrence of the 54 recoveries with adipose and left pelvic fins off the inclination might have been to accept the 102 individuals with adipose and right pelvic fins off as authentic Eagle river fish. Under the circumstances, therefore, if the former—all four year individuals and therefore not Eagle river fish unless incorrectly marked—are assumed to be poorly or incorrectly marked Cultus lake sockeye, those with the adipose and right pelvic fins missing may also belong to the Cultus lake group.

In table II are given the mean lengths and weights for samples of the three groups of marked fish in question. While the means for specimens with adipose and right pelvic or adipose and left pelvic fins removed are greater than for those with adipose and both pelvics missing the differences are statistically significant only for females. The size measurements for female sockeye with adipose and one pelvic off are less than would be expected in a pure strain of Eagle river fish of Adams river origin yet greater than for Cultus lake individuals wherefore the assumption might be that these groups represented a mixture of both Eagle river and Cultus lake fish.

TABLE II. Length and weight data for sockeye recovered in the commercial fishing areas with (1) adipose and both pelvic fins missing (Cultus lake mark for four year fish), (2) adipose and right pelvic fins lacking (Eagle river mark for four year fish) and (3) adipose and left pelvic fins (Eagle river mark for three and five year fish).

	Adipose and two pelvics		Adipose and right pelvic		Adipose and left pelvic	
	Male	Female	Male	Female	Male	Female
Number of individuals	175	218	48	36	27	17
Mean length, cm.	59.8	57.0	60.3	58.1	60.0	58.9
Standard error, length	0.12	0.11	0.50	0.42	0.57	0.87
Mean weight, kg.	2.51	2.12	2.56	2.27	2.63	2.33
Standard error, weight	0.035	0.025	0.054	0.054	0.081	0.097

The exact identification of these sockeye with adipose and one pelvic fin missing is therefore impossible and it can only be said that they may have been either authentic Eagle river fish (adipose and right pelvic off), poorly marked Eagle river fish (adipose and left pelvic fin off) or all poorly marked Cultus lake individuals. Actually, if all of the fish in question were credited to the Eagle river planting of 1930, the return would be a very poor one, 0.04 per cent of fingerlings released, as compared with 1.9 per cent and 2.6 per cent for recoveries of Cultus lake marked fish in the fishing areas in 1932 and 1933 respectively (Foerster 1936b).

The 43 recoveries (23 males and 20 females) from the fishing areas in *1934* would appear to be genuine returns from the Eagle river liberation in 1931 of fingerlings with left pelvic and adipose fins removed. Average lengths were: Males, 12 individuals, 64.5 cm.; females, 8 individuals, 61.7 cm. Examination of the scales showed them to be fish in their fourth year. Other sockeye with the left pelvic and adipose fins lacking were also taken in the fishery but in all cases these were fish in their fifth year, hence presumably incorrectly marked individuals from the Cultus lake smolt marking of 1931. No smolts were marked at Cultus lake in the spring of 1932, hence returnable as four-year fish in 1934.

During the *1935* season no reports of capture of marked adults in the commercial fishery were received from either fishermen or cannery workers. No special campaign to examine sockeye landed at canneries was undertaken.

Summing up, in all years when the catches were specially examined, some of the Eagle river marked sockeye were taken in the commercial fishery. These recoveries, small in number in comparison with the numbers of marked fingerlings released, tend to indicate that some of the fish at least reached the ocean and were returning to spawn.

(b) RETURNS TO PARENTAL SPAWNING AREAS

CULTUS LAKE

None of the marked fish taken at Cultus lake in 1932, 1933, 1934 and 1935 could be properly attributed to the Eagle River markings of 1929 and 1932,

all being possibly Cultus lake markings although not certainly so. In 1932, five males lacking left pelvic and adipose fins were observed at Cultus lake. Four were of small size, 48.0, 47.0, 50.5, and 42.5 cm. and were unquestionably three year olds. The fifth, 55.0 cm. in length, may also have been of the same age group (Foerster 1936a). All of these fish, therefore, undoubtedly belonged to the Cultus lake marking of 1931 (Foerster 1936b) but had the right pelvic fin imperfectly removed. In 1933, 9 males and 8 females with adipose and left pelvic fins off and 3 males and 3 females with adipose and right pelvic fins lacking were recovered. Due to absorption of the scale margins it was impossible to determine the ages of these individuals, for example, whether those specimens with adipose and left pelvic fins off were five year fish—as they would be if authentic Eagle river fish—or were all four year olds, hence mis-marked Cultus lake individuals but it is strongly suspected that all were poorly marked Cultus lake fish. No fish bearing Eagle river marks were retaken at Cultus lake in 1934 or 1935, although in the latter year a return from the sea of marked fish from the second Cultus lake transplantation to Eagle river was expected.

ADAMS RIVER

Since Adams river joins the Shuswap system some distance below Eagle river it might be argued that in all probability the returning adults which had been reared to fingerling stage in Eagle river would be attracted into their parent stream along with the normal run to that area. There was little hope of adequately checking on this possibility but in 1934 a visit was paid to the Adams and one thousand dead sockeye, selected at random in two stretches of the stream, were closely examined for marks. Not one marked individual was encountered.

It is difficult to make any quantitative assessment of the probability of occurrence of Eagle river marked fish in the Adams river run but from the data obtained at Cultus lake on the return of marked sockeye to their parent stream (Foerster 1936b) it was found that of marked migrants liberated 1.8% returned in one experiment and 0.9% in a second. Assuming, then, that 1.0% of the Eagle river marked fingerlings survived to return to Adams river as adults, the return would amount to approximately 3,000 in 1934. If the escapement to Adams river totalled 500,000 fish, a high estimate, the marked fish should have, under conditions of random distribution, constituted 6 per 1,000 individuals. On this basis, according to the fiducial limits given by Ricker (1937) with a 0.99 confidence coefficient, from 1.5 to 15.6 marked individuals should be expected to occur in a sample of 1,000 sockeye.

Since no marked sockeye were found a reasonable conclusion would therefore be that there was little, if any, return to Adams river of the marked fingerlings of Adams river origin but reared in the retaining ponds at Taft and released into Eagle river.

(c) RETURN TO THE PLANTED AREA

The results (table I) reveal that no success attended the use of Cultus lake eggs, taken from a lower Fraser tributary stream, approximately 70 miles

(113 km.) from the ocean, in 1929 and 1932. Even from the relatively closely-adjacent stream, Adams river, in the same Shuswap area to which Eagle river is tributary, only a small return, three individuals in one year and seven in the second, was achieved from the egg transfers of 1930 and 1931. The unmarked fish recorded in table I show that in every year sockeye ascended to Eagle river from the sea.

It may be of interest to record that in the spring of 1929 the Department of Fisheries carried out a planting of 16,000,000 sockeye salmon eggs of Cultus lake origin in Eagle river under expert supervision. This planting was quite independent of the experiments reported above. Reference to table I will reveal that the return in 1932 of unmarked adults was extremely small, 20 individuals. Hence this planting proved equally unsuccessful in producing any restoration of a sockeye run to Eagle river.

(d) Possible Explanation of Restocking Failure

One striking and perhaps significant feature of the evidence obtained from the experiments is the fact that so very few of the Eagle river marked adults were recovered in the commercial fishery. Recaptures in 1932 constituted approximately 0.01 per cent of fingerlings liberated and in 1934 only 0.015 per cent were retaken. Even if all the 104 recoveries recorded for 1933 were considered as genuine they would have represented only approximately 0.04 per cent of fingerlings liberated in 1930.

Comparison of these returns with those from two marking experiments at Cultus lake (Foerster 1936b), which resulted in recoveries on the fishing grounds of 1.9 per cent and 2.6 per cent of seaward migrants marked and liberated, strongly suggests that the Eagle river marked fingerlings either (1) suffered heavy mortality following release from the retaining ponds, (2) wandered to other rivers along the coast or (3) remained in Shuswap lake as lake-dwelling "residuals" (Ricker 1938). There would appear to be no reason to presume that the Eagle river sockeye would suffer any greater mortality in the ocean than Cultus lake individuals.

The conclusion, therefore, seems to be that the Eagle river fingerlings in large part never did reach the ocean but were either killed off prior to normal seaward migration or remained permanently in the Shuswap lake system. No information is available on the point but even if it were the case the fact remains that the restocking, for the purpose of restoring a run of sockeye to Eagle river, was a failure.

CONCLUSION

It may be concluded, therefore, that mere transfer of eggs from one area to another will not necessarily result in an increase in the spawning stock returning to the new area. It was at first thought that the use of lower Fraser river stock to restore the runs to the upper river where decidedly longer up-river migrations are required might be unwise and unsound because of the possible inability of the lower river "races" to meet the long and gruelling ascent of the river to the new areas. It seems evident now, from the experiments with Adams

river eggs, that use of upper Fraser river stock that has shown the ability to make the ascent of the river to the Shuswap area is also not effective. Other factors must be involved and these should be elucidated before further transplantings are made, if restocking is to be successful.

SUMMARY

An experiment was undertaken in 1929 to test the method of transferring sockeye salmon eggs from well-populated areas in order to restore the populations in those suffering severe decline. Eagle river, tributary to the once highly-productive Shuswap lake area, was selected for the experiments and eggs from a lower Fraser river tributary—Cultus lake—and from an upper Fraser river tributary—Adams river, in the Shuswap lake system—were used for comparison.

Transfers from Cultus lake were made in 1929 and 1932 and 123,500 and 293,800 fingerlings, respectively, were marked and liberated. A total of 12 adults were recovered in the fishing areas in 1932 but none were reported in 1935. At Eagle river itself none were taken at the counting weir in 1932 and none were observed in 1935 in a survey of the spawning fish.

Transfers from Adams river were made in 1930 and 1931 when 271,600 and 287,800 fingerlings, respectively, were marked and liberated. A total of 104 sockeye bearing the correct Eagle river mark (right pelvic and adipose fins off) used in the first Adams river transplant were taken in the fishing areas in 1933 but owing to the occurrence of marked sockeye from Cultus lake (two pelvics and adipose off) in the same year it cannot be clearly demonstrated whether the fish carrying the Eagle river marks were genuine or were poorly-marked individuals bound for Cultus lake. From the second Adams river test, 43 adults were recovered in the commercial fishery in 1934. At Eagle river itself, 3 returns from the first Adams river transplant and 7 from the second were obtained. No marked fish were seen in the native Adams river area in 1934.

Unmarked sockeye occurred in Eagle river in each year (20, 13, 49 and 17 respectively), showing that some ascended to Eagle river from the sea. In the spring of 1929 the Department of Fisheries planted 16,000,000 eggs from Cultus lake, but there was no significant increase in the run to Eagle river in 1932.

From the experiments the conclusion is reached that egg transfers definitely failed to restore the sockeye runs to the depleted Eagle river area, there being either no returns (Cultus lake eggs) or very small returns (Adams lake eggs).

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Effect of Trimethylamine Oxide on the Growth of Bacteria

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ABSTRACT

It has been shown that the addition of 1% trimethylamine oxide to culture media reduces the total counts from fresh cod fillets approximately fifty per cent when the plates are incubated at 25°C. or lower.

By plating out pure cultures it has been shown that the inhibiting action of the oxide is on gram positive organisms and has either no effect or a slight stimulating action on gram negative organisms.

INTRODUCTION

One characteristic of most marine fish is the presence of relatively high concentrations of trimethylamine oxide. Beatty (1939), analysing muscle press juice from fish found in Nova Scotia waters, has shown that the percentage of this oxide varies from 0.26 in the flounder to 1.43 in the dogfish. Cod, smooth skate, hake and pollock were found to have 0.67, 0.53, 0.80 and 0.48 per cent respectively.

It has been shown (Suwa 1909, Beatty and Gibbons 1937, Beatty 1938, etc.) that the reduction of this oxide to its corresponding amine is one of the initial changes in the normal spoilage of many types of sea fish. Beatty and Gibbons (1937) have shown that the reduction of trimethylamine oxide is brought about by microbial activity. Wood and Baird (1943), Wood, Baird and Keeping (1943), and Baird (unpub.) have demonstrated that a wide variety of bacterial species are capable of bringing about this reduction.

No attempt has been made by these workers to determine whether the oxide exerts any influence on the growth and activity of the bacteria, or whether it has any selective action on the microflora developing on fish during handling and storage. Some preliminary experiments carried out in this laboratory suggested that the oxide does have a selective action on certain types of bacteria. The work recorded in this paper has been an attempt to observe more carefully this effect of trimethylamine oxide on the growth of bacteria.

The trimethylamine oxide used in these experiments came from two sources. Some was obtained from Lederle Laboratories and some was prepared at this Station by oxidizing trimethylamine with hydrogen peroxide and distilling under a partial vacuum at 50°C. It was further purified by recrystallization several times from alcohol. Simi ar results were obtained from both lots of oxide.

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EFFECT IN MIXED CULTURES

Cod fillets, sea water and various other materials were plated out in culture media with and without the addition of one per cent of trimethylamine oxide, and a comparison was made of the "total counts" obtained.

Cod Fillets

Six fillets were thoroughly macerated in a sterile Waring blendor, and plated out on a nutrient agar (0.2 per cent each of peptone, yeast extract, beef extract and dextrose in a 1.5 per cent solution of agar in sea water), and in Zobell's medium (1941) for cultivating marine bacteria. A similar set of plates was poured using the same media except that one per cent of the oxide had been added. These were incubated at 3°C., 7°C. and 25°C., and the counts made at 17, 7 and 3 days respectively. The results are shown in table I. The average inhibition of the oxide, calculated from the counts given in this table, is 47.5 per cent. In other words, only about half as many colonies developed in these media when one per cent oxide was added.

Table I. Plate counts (thousands of organisms per g. of fish) from cod fillets in Zobell's medium and in a nutrient agar incubated at 25, 7, and 3°C. with and without the addition of one per cent trimethylamine oxide.

		25°C.		7°C.		3°C.	
Sample	Medium	+ oxide	− oxide	+ oxide	− oxide	+ oxide	− oxide
1	Z	180	310	69	131	22	44
	N	190	290	42	96	17	22
2	Z	160	340	64	204	32	56
	N	160	330	44	134	23	51
3	Z	180	200	37	115	24	24
	N	220	370	25	72	2	21
4	Z	800	1380	307	582	98	196
	N	840	1290	187	427	68	98
5	Z	750	1600	301	960	151	263
	N	750	1560	207	631	108	240
6	Z	960	1500	197	613	128	128
	N	1170	1970	133	384	62	112

A second series of 14 cod fillets, direct from the cutting tables of a commercial fish plant, were plated out, with and without added oxide in the nutrient agar medium used previously. Plates from this series were incubated at 37°C. as well as at 25, 7 and 3°C. As far as possible the number of days the fish had been out of water was obtained from the foreman of the fish plant. Where the fillets were fresh, and the plates incubated at 25°C. or below, the counts in the medium to which oxide had been added were almost invariably lowered (table II). At 37° C. incubation temperature these results were reversed in almost half of the samples; and with the "five day old fish" there was either no significant difference between the counts, or those in the oxide-containing medium were higher.

TABLE II. Plate counts (in thousands per g. of fish) in a nutrient agar with and without added trimethylamine oxide from 14 cod fillets, one to five days after being caught, made at four different temperatures. Figures in italics where counts on oxide-medium exceed those of control plates.

	37°C.		25°C.		7°C.		3°C.	
Days old	+	−	+	−	+	−	+	−
5	*410*	220	*1140*	670	*267*	150	*151*	49
5	*44*	18	*880*	538	*227*	130	*160*	18
5	*236*	60	4800	5300	*770*	720	*157*	17
3	34	84	256	550	120	410	79	174
3	*36*	28	402	808	116	336	32	84
3	*844*	769	1356	2044	1418	1791	604	1009
3	8	19	44	667	307	597	342	627
3	23	106	500	578	262	587	444	546
3 (?)	*283*	10	2760	4000	450	510	116	138
3 (?)	3	11	63	67	24	29	10	28
3 (?)	44	50	100	210	41	86	18	24
1	13	24	137	132	84	155	*89*	69
1	5	2	*130*	107	103	137	17	19
1	*29*	8	180	180	120	155	57	75

Evident to the observer, but not apparent from the tables, is the difference in the general appearance of the colonies on these plates. Many organisms appeared to grow equally well on either medium. Instead of having a general depressing action on all bacterial growth, the oxide seemed to be selective, and only certain types were affected by it.

WATER SAMPLES

Twelve samples of sea water were plated out in media with and without added oxide. Four of these were obtained from the Quereau fishing banks and had been held for almost two weeks in small, stoppered bottles. Four were obtained close to shore in an unpolluted area. Two were heavily polluted harbour water samples. The remaining two were samples of water that had been used aboard ship for washing gutted fish.

There was no significant difference in the counts of the unpolluted water samples. Those from the harbour water were slightly higher in the oxide plates. The counts from the fish wash water were just over three times as numerous on the plates without the oxide.

Similar tests on 17 samples of city tap water invariably gave much higher counts on the oxide-free medium. These counts ranged from 8 to 70 times greater in the absence of the oxide.

MISCELLANEOUS MATERIALS

Inocula from soil, milk and other materials were also plated out in media with and without the addition of one per cent trimethylamine oxide. The results were much the same as those described above. From the soil samples,

the counts were decreased on an average of five times, when the oxide was added. The counts from commercially pasteurized milk showed more variation; some showed a slight difference and some were reduced more than 50 per cent by the addition of the oxide. By adding one per cent of the oxide directly to the milk, before the bacteria became too numerous, the samples with and without the oxide spoiled differently. Without oxide, the milk was more readily peptonized and added Eh indicators were more quickly reduced; with oxide the spoilage rarely developed past a smooth curd. In several tests, milk to which oxide had been added remained unchanged in appearance for more than a week at 25°C. while the controls were almost completely digested.

These results indicate that the inhibiting action of the oxide does not act uniformly on the microflora of different types of materials. There is much to suggest, as shown by the tests on pure cultures, that it is owing chiefiy to the differences in the types of bacteria they contain, rather than to any inherent differences in the materials themselves.

Growth of bacteria from cod fillets cut from relatively fresh fish was inhibited approximately 50 per cent when the plates were incubated at 25°C. or lower; at 37°C. growth was equal to or in some cases more rapid in the presence of the oxide.

The oxide substantially reduced the count from tap water, soil, pasteurized milk, dust, etc., but had relatively little effect on counts from polluted harbour water or sea water that had been kept in closed containers from 3 to 37 days.

The addition of one per cent oxide to whole commercially pasteurized milk brought about marked changes in the rate and type of spoilage that developed subsequently.

These results, together with observations made on the colonies in the plates indicate that the inhibition of the oxide is not general, but affects only certain types of bacteria.

EFFECT IN PURE CULTURES

Aerobes

Dilutions made from pure cultures of bacteria were plated out on agar media with and without the addition of one per cent trimethylamine oxide. In most instances the medium used was standard nutrient agar plus 0.5 per cent dextrose. The pH of the control medium was about 7.1. The oxide medium after autoclaving was slightly more alkaline, pH 7.2 to 7.3. The plates were incubated at 25°C.

Observations consisted of noting the rate at which the colonies became visible both microscopically and macroscopically, the relative size and number of colonies in corresponding plates, and other changes in the colonies resulting from the presence of the oxide. It was observed, for instance, that *Micrococcus aureus* was not only retarded in growth, but also showed reduced pigmentation and less surface growth in the oxide plates.

In most instances where the oxide affected the rate of growth, it was more pronounced on the plates containing relatively few colonies.

In general there were three types of reaction to the oxide; in a few instances it appeared to be beneficial, and increased the growth rate; in others it had no apparent effect; in still others it retarded, but rarely inhibited development of the colonies.

Among the organisms tested, the following were either stimulated or unaffected by the oxide: *Escherichia coli*, *Aerobacter aerogenes*, *A. cloaceae*, *Proteus vulgaris*, *Serratia marcescens*, *Pseudomonas fluorescens*, *Ps. denitrificans*, several species of *Flavobacterium* and 20 unidentified gram negative organisms isolated from fish.

Those definitely retarded by the oxide include: *M. aureus*, *M. candicans*, *M. epidermidis*, *M. citreus*, *Bacillus subtilis*, several unidentified spore-forming rods and colonies of yeast-like organisms isolated from sea-water.

In a few cases the amount of retardation was questionable. These include *B. cereus*, *Eberthella typhi*, and some cocci isolated from fish.

From this it can be seen those organisms which are retarded by the oxide are gram positive and those unaffected are gram negative. There seems to be no relationship between the ability of an organism to utilize the oxide as a hydrogen acceptor and the retarding action of the oxide on the growth of the bacteria. The *Pseudomonas* cultures cannot reduce the oxide, while the organisms of the colon group can reduce it. Neither are retarded in growth by the presence of the oxide in the medium.

Anaerobes

In the first series of tests a glucose-brain-heart infusion medium was used. The oxidation-reduction potential was poised at a reducing level suitable for anaerobic growth by the addition of 0.1 per cent sodium thioglycolate. Previously sterilized trimethylamine oxide was added after the medium was autoclaved to give 0, 0.5 and 2.0 per cent solutions. These were inoculated with one drop from active broth cultures of *Clostridium botulinus*, *C. butyricum*, *C. sporogenes*, *C. tertium*, *C. difficile*, *C. aerofoetidum* and *C. sphenoides*. They were incubated at 37°C. After 48 hours there was abundant growth in all the oxide tubes except those inoculated with *C. difficile* and *C. sphenoides*.

In a second series the sodium thioglycolate was omitted. During the first 36 hours there was much less growth in the tubes containing 0.5 per cent oxide, and none in those containing 2.0 per cent oxide. At 72 hours growth was evident in all the 2.0 per cent tubes except those inoculated with *C. difficile* and *C. sphenoides*. The amount of growth in the oxide tubes varied considerably with different cultures; in some, the oxide tubes were indistinguishable from the controls; in others there was very much less growth.

In a third set the medium used consisted of: Difco-brain-heart infusion, 25 grams; dextrose, 5 grams; K_2HPO_4, 1 gram; agar, 0.5 gram; water, 1,000 ml. After sterilizing the media in test tubes, previously sterilized trimethylamine oxide was added to give 0.5 and 2 per cent solutions. Instead of using a drop of culture to inoculate each tube, they were inoculated by transferring one ml. from a series of dilutions made from the cultures. Eight pure cultures were used. During the first 36 hours of incubation, growth of four of these cultures

was slightly retarded in the higher dilutions (i.e. containing fewer cells in the inoculum) in the tubes containing the 0.5 and 2 per cent oxide. After this period the difference became less noticeable and ultimately abundant growth was observed in almost all tubes, with and without oxide. Organisms in this group included *C. butyricum*, *C. botulinus*, *C. sporogenes* and *C. thermosaccharolyticum*. A second group of organisms was permanently inhibited in the higher dilutions by the presence of 0.5 or 2 per cent oxide, and in those tubes when growth did occur in the presence of the oxide it was very scanty compared to the controls. Organisms of this group included *C. tetani*, *C. difficile*, *C. sphenoides*, one strain of *C. welchii*, *C. pasteurium* and *C. multifermentans*.

Intermediate between these groups are *C. tertium*, *C. paraputrificum*, *C. putrificum* and *C. aerofoetidum*.

Similar experiments with various modifications were repeated many times. The results were approximately the same and can be summed up in the following:

A. The retarding or inhibiting action of the oxide on the growth of anaerobic spore-formers varied greatly with the medium that was used. It was least in media containing strong reducing agents such as sodium thioglycolate and most in poorly poised media. Generally speaking the poorer the control medium was for growing anerobes the more effective was the oxide in retarding growth.

B. The effect of the oxide varied with different organisms. *C. botulinus*, *C. butyricum* and some strains of *C. sporogenes* were the least affected by it, and *C. sphenoides*, *C. pasteurianum* and *C. difficile* were the most easily depressed. The amount of growth in the oxide tubes, once proliferation had been initiated, also varied greatly. Those organisms which were found to produce ultimately large numbers of cells in the presence of the oxide (*C. botulinus* and *C. butyricum* and some strains of *C. sporogenes*) were tested for their ability to reduce the oxide, and were found to be positive, while the others were negative.

EFFECT OF pH

Although not fully investigated, there is reason to believe that pH affects to a marked degree retardation by the oxide of the growth of some bacteria. In a number of tests M. *aureus*, *B. subtilis* and *E. coli* were plated out on oxide and oxide-free media buffered with phosphate NaOH solutions to give pH 6.0, 6.5, and 6.8 respectively. After autoclaving, the medium containing the oxide was in each case more alkaline by pH 0.1 than the controls.

With *E. coli* there was no observable difference in growth in this pH range. With *B. subtilis* and *M. aureus* the colonies containing oxide were smaller and fewer at pH 6.0. At pH 6.5 the difference was greater, and at pH 6.8 only a relatively few colonies grew on the plates from the lower dilutions.

A similar test with a yeast-like organism isolated from water resulted in the complete inhibition of colonies on the oxide medium when the pH was raised above 7.0, although corresponding control plates produced normal colonies.

DISCUSSION

From the results it would appear that the presence of one per cent trimethylamine oxide added to agar culture media retards the growth of certain types of bacteria in a mixed microflora. It has been shown by a comparison of the growth of pure cultures in oxide and oxide-free media that the retarding action is effective only on certain gram positive bacteria.

If a similar reaction occurs as a result of the trimethylamine oxide in fish, one would expect a selective action as the microflora develops. Gram positive micrococci which are very prevalent in fish slime and on the surface of freshly caught fish might gradually give rise to a flora of gram negative rods. It was found (table II) that only those fillets from the fish that had been caught at least five days had a higher count on the oxide medium. This would indicate that the flora were predominantly gram negative rods. The exceptions to this were the counts of certain fillets plated at 37°C. At this temperature quite a different flora develops from those growing at room temperature or below. Many species of the Enterobacteria, including fecal types, are encouraged, while many psychrophilic types are inhibited.

Chertkova *et al.* (1940) in their study of the alterations in the microflora of stored frozen fish, found just such a change to take place. The micro-organisms on relatively fresh fish were composed mainly of cocci, and during the initial stages of spoilage the proliferation of rod-shaped bacteria, chiefly *B. proteus*, *B. vulgaris* and *B. fluorescens* was observed. Wood (1940) in his study of the bacteriology of fish spoilage similarly found that the earliest invaders of fish muscle were *Flavobacteria* and *Micrococci*, but that later these two had been replaced in importance by the gram negative *Achromobacter* and *Pseudomonas*. It is of interest to note that although Wood (1940) found a small percentage of spore-forming rods almost invariably present in market fish, these organisms never developed into predominance.

If it should prove that the oxide in the sea fish so affects the microflora as it appears to do in culture media, one cannot help but wonder if this might not also offer some explanation of the reputedly more rapid spoilage of the oxide-free fresh water fish when compared to the marine types.

At the present time no explanation can be offered as to the mechanism by which the oxide retards or inhibits the growth of certain types of bacteria.

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The Mud-Blister Worm, Polydora, in Canadian Oysters

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ABSTRACT

Polydora ciliata causes mud blisters, often inconspicuous, on the shells of oysters (*Ostrea virginica*) in deep water, in the intertidal zone and in floating trays in many important producing areas but is of industrial importance only in parts of the Bras d'Or lakes, N.S., where salinities are low and the bottom soft. *Polydora* has no significant effect on the fatness of oysters and is unlikely to create a major industrial problem unless hydrographic conditions change.

Polydora ciliata (Johnston) is an inconspicuous annelid often commensal in marine mollusks, generally oysters. In oysters it establishes itself between the pallium and the shell near its margin and accumulates a mass of mud in which it lives and over which the oyster eventually secretes a transparent film of limey shell to produce a blister. The blisters generally observed are at least a square centimetre in area, raised a millimetre or more above the general surface of the shell and filled with a black mud that makes them conspicuous. In some cases large adjacent blisters overlap and build up to such depths that heavily infected oysters may be unable to close their shells. It is not generally appreciated that the blisters may be quite small, scarcely raised, and contain so little mud as to be almost transparent and inconspicuous.

DISTRIBUTION

This species has been reported from England (Lebour 1907, Wilson 1928) where it attacks oysters and mussels, from Australia (Roughley 1922) where it is the scourge of the oyster industry and from the Atlantic coast of the United States (Lunz 1940 and 1941) where it is also of industrial importance. Willey and Huntsman (1921) found it in the Fundy area (Passamaquoddy bay) both free-living and in obscure association with the whelk, *Buccinum*. An allied species, *P. ligni*, is reported to have destroyed several hundred thousand dollars' worth of oysters in Delaware bay in a single season (Nelson and Stauber 1940).

In 1938 the writer discovered worms of this genus in blisters on the inner surfaces of shells of oysters from River Denys, N.S. Records were kept of the incidence of infection in the oyster population, of the intensity of infestation and of the average size of the blisters. Since that time more information of the same sort has been assembled for different areas. All our records are summarized in table I.

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TABLE I. Summary of information on *Polydora* in Canadian waters. Percentage of oysters infected, based on counts of samples of about 100 oysters in each place ecxept Malagash, where the sample was only 10.

Place	Year discovered	Oysters infected (%)	Worms in infected oysters (average number)	Average area of blisters (sq. cm)	Average thickness of blisters (mm.)
Bras d'Or lakes, N.S.					
River Denys at Crowdis bridge	1938	75	2-3	2	1-2
North basin, River Denys	1939	37	2.4	1-2	1-2
Gillis cove (1) adults from bottom	1939	25	1.5	1-2	1-2
(2) large tray spat of 1938 set	1939	4	1.0	1-2	1-2
Malagawatch basin	1939	33	3.1	1-2	1-2
Tatamagouche bay, N.S.					
On oyster reef exposed at low tide in Malagash basin	1939	30	1.0	<1	<1
In Bideford river, Malpeque bay, P.E.I.					
Cooper bed near mouth of river	1939	0	...	...	...
Sand bed, half-way up river	1943	ca. 15	1-2	<1	<1
Upper reaches of river (Smelt creek)	1944	32	1.5	<1	<1
St. Simon inlet, N.B.	1944	<5	1.0	<1	<1
Tracadie, N.B.	1944	<5	1.0	<1	<1

Because *Polydora* had received little attention in Canada and might prove to have industrial importance, an enquiry about mud blisters was made among fishermen in every district where it was discovered. The results show that the Bras d'Or lakes are the only waters where the blisters are conspicuous enough to have attracted general attention. The fishermen there state that blisters have been present in their oysters as long as they can remember and that to their knowledge there have been no radical changes in their size or abundance in oysters from any of the beds they fish.

No evidence was found of mortalities of the sort described by Nelson and Stauber (1940) or of any other destruction that could be attributed to *Polydora*.

SPECIFIC IDENTITY OF CANADIAN *POLYDORA*

Specimens of the worms removed from blisters of Bras d'Or and Malpeque oysters were sent to Mr. and Mrs. C. J. Berkeley of the Pacific Biological Station, Nanaimo, B.C., for identification. The Malpeque worms were all identified as *P. ciliata*. The Bras d'Or specimens, however, showed structural

variations. Some had the typical *P. ciliata* structure, some fitted Hartman's description of her recently established species *P. websteri* (Loosanoff and Engle 1943) while others were intermediate.

DISTRIBUTIONAL RELATIONSHIPS

Blisters were generally more common on lower than on upper valves of oysters. A sample of twenty-four infected oysters taken from Bideford river, P.E.I., on September 5, 1944, showed, in all, thirty-five blisters, of which twenty-four were on lower and eleven on upper valves. Loosanoff and Engle (1943) report similar findings for *P. websteri.*

Small Gillis cove tray oysters that had never been in contact with the bottom were infected indicating that it is the free-swimming stage of *Polydora* that infects oysters. However, the percentage infection in tray stock was lower than in older oysters on the bottom (table I). In this respect Gillis cove conditions differ from those in Milford harbour (Loosanoff and Engle 1943), where all tray oysters, large and small, showed heavier infection than any of those living on the bottom and resemble those in Australia (Roughley 1922) where oysters reared above the bottom are not seriously infected.

Malagash oysters taken from reefs that are exposed at low tide showed a thirty per cent infection, proving that in our areas the worm occurs in the intertidal zone.

Table I shows that the percentage infection, the intensity of infestation and the size of the blisters were greatest in the Bras d'Or lakes where salinities are prevailingly low (Medcof and Needler 1941). Within this area they reached their maxima in the upper part of River Denys where the salinities are the lowest of all and the bottom is of soft mud. The records for Malpeque bay, where salinities are high (Medcof 1946), show a similar trend. Apparently the heads of inlets where the salinities are lowest and the bottoms softest provide the best conditions for blister worms. This is the opinion expressed by Lunz (1941).

The other records show that the species is widely distributed in the oyster producing areas of the Maritime provinces.

VARIATION IN SIZE OF BLISTERS

The table shows that there is much variation in the size of mud blisters from district to district. In the writer's opinion this is the result of differences in the length of the period between *Polydora* infection and the initiation of calcareous shell secretion. During this interval the growing worm accumulates the mass of mud in which it lives. After the calcified blister is formed the amount of mud the worm can collect is strictly limited. It has been shown (Medcof 1944) that of the areas studied, shell secretion is interrupted to a large extent by low salinities in spring and fall, only in the Bras d'Or lakes. If low salinities were to occur about the time of infection they could lengthen the "mud-collecting" period and thus indirectly regulate the size of the blisters. Such a mechanism provides at least a plausible explanation for the great size of the Bras d'Or blisters.

TABLE II. Individual indices of condition (I), of 163 Bras d'Or lakes (N.S.) oysters in 18 lots with corresponding numbers of worms (N), infecting each.

Place	Gillis Cove							
Date	June 16		Oct. 19		Nov. 10		Nov. 12	
	I	N	I	N	I	N	I	N
	109	0	85	0	61	0	66	0
	48	0	89	0	76	0	87	0
	57	0	106	0	38	0	52	0
	59	0	51	0	44	0	107	0
	57	0	115	0	41	0	93	3
	97	2	106	0	66	0	94	1
			126	0	40	1	114	1
			73	0	51	1	83	2
			85	1	60	1	82	1
			81	1	43	1	60	3
Mean index								
Infected	97		83		49		88	
Uninfected	66		94		54		78	

(19 worms in 13 oysters)

Place	North Basin													
Date	June 15		July 11		Sept. 1		Oct. 23		Sept. 26		Nov. 19		Nov. 21	
	I	N	I	N	I	N	I	N	I	N	I	N	I	N
	65	0	25	0	47	0	88	0	79	0	103	0	102	0
	102	0	76	0	31	0	51	0	52	0	106	0	71	0
	54	0	71	0	74	0	85	1	72	0	112	0	44	0
	72	0	54	0	56	0	70	2	56	0	78	0	82	0
	78	2	53	0	58	0	122	1	60	0	48	0	82	0
			58	0	40	0	118	10	69	2	66	0	129	0
			55	0	54	0	76	5	84	2	72	1	47	0
			50	0	71	1	56	1	58	2	51	1	92	1
			46	0	68	1	37	1	82	2	51	5	74	1
			51	2	51	1			61	2	36	2	69	4
Mean index														
Infected	78		51		63		94		67		53		78	
Uninfected	73		54		51		70		64		86		80	

(53 worms in 24 oysters)

Place	Malagawatch											
Date	July 6		July 7		July 14		July 24		Nov. 2		Nov. 19		Nov. 22	
	I	N	I	N	I	N	I	N	I	N	I	N	I	N
	65	0	48	0	98	0	57	0	105	0	111	0	99	0
	53	0	76	0	74	0	35	0	135	0	116	0	124	0
	62	0	68	0	58	0	55	0	123	0	136	0	74	0
	50	0	50	0	61	0	57	0	116	0	91	0	108	0
	66	0	80	4	79	0	43	0	99	0	102	0	107	0
	60	5			45	0	46	0	84	0	103	0	102	3
	96	2			58	0	55	0	108	0	109	1	111	1
	57	1			76	1	58	5	56	0	99	3	80	1
	55	2			82	1	68	7	108	2	61	4		
	68	5			65	10	52	2	113	1	92	1		
Mean index														
Infected	67		80		74		57		111		53		98	
Uninfected	59		61		68		50		103		86		102	

(62 worms in 21 oysters)

Effect on Condition of Oysters

Using the index of condition developed by Medcof and Needler (1941), Lunz (1941) studied the fatness (plumpness of meats) of individual oysters, infected and uninfected. He concluded from measurements on a total of 67 animals that those with no or only one blister had a 14% higher index than those with two or more blisters. There is no suggestion in his report that any precautions were taken to insure that the samples of oysters he tested were representative and comparable. It has been demonstrated that both the fatness of oysters and the intensity of their infestation by *Polydora* are correlated with the depth of water in which the oysters live (Nelson 1930, Roughley 1922). Other factors such as position in the estuary, bottom character, salinity, water temperature, spawning activity and disturbance are known to be important in regulating fatness (Medcof 1946, Medcof and Needler 1941) and these must all be allowed for in sampling. Unless he took such precautions, Lunz's conclusion is unjustified.

In 1939 the writer measured the index of condition "I" of 163 Bras d'Or lakes (N.S.) oysters, 75-100 mm. long, taken in 18 lots, usually of 10 each. Of these, 36 oysters in 4 lots came from a plot 8 m. square, in water 1.5 m. deep at low tide, in Gillis cove. Seven lots containing a total of 64 oysters, came from a similar plot in North Basin of River Denys and seven others with a total of 63 oysters from a similar plot in Malagawatch harbour. The lots were fished at different dates from June 16 to November 22 so that each of the three stocks of oysters was examined while in several different phases of its annual cycle of fatness changes. The original data appear in table II.

Of the 163 oysters, 105 had no blisters while the 58 others had blisters in varying numbers whose mean with standard error was 2.31 ± 0.09. The largest number found in any one oyster was 10.

The indices for infected, "I_i", and for uninfected oysters, "I_u", varied greatly and showed much overlapping both within lots and from lot to lot. The over-all mean for the index of the 163 oysters with its standard error was 74 ± 15.

The conditions of sampling were such that it is justifiable to compare the index of infected and uninfected oysters only within each of the 18 individual lots. The effect of infection on fatness in each lot was measured by "d", the difference between the mean index for uninfected, "$\bar{I}_u$", and infected, "$\bar{I}_i$". Each "d" value was weighted according to the number of infected, "n_i", and the number of uninfected, "n_u", oysters whose indices contributed to this difference to get a weighted difference "wd". From the 18 weighted differences a weighted mean difference, "$\bar{d}$", was calculated. The analysis of the data is summarized in table III.

When the weighted mean square of the deviations of these weighted differences from their mean is compared with the pooled within-lots variance for both infected and uninfected oysters (table III) it is found that they are not significantly different. The "F" value obtained, 1.03, is well below 2.00, the tabulated value for F at the 5% level of probability. Following Yate's reasoning (1933), it is concluded from this that there are no important interactions of the infection-fatness effect with season, locality, etc., and, therefore, that the use of the weighted mean difference is justified in comparing the indices of infected and uninfected oysters.

The importance of the weighted mean difference, + 0.67, which suggests that infected oysters are fatter than uninfected, can be estimated from the "t" value, 0.19, (table III). This is well below 2.11, the corresponding tabulated value for t at the 5% level of probability. From this it is concluded that infection had no significant effect on fatness.

The above conclusion is supported by the fact that when the pooled within-lots variances for infected and for uninfected oysters are compared there is no evidence of heterogeneity in the population as a whole, in spite of a considerable range in the intensity of infection in the blistered oysters. The "F" value obtained, 1.21, (table III) is well below 1.60, the appropriate "F" value at the 10% level of probability. Since in this case the test is "two-sided", the tabulated "P" value, 5%, corresponding to an "F" ratio of 1.60, has been doubled.

INDUSTRIAL STATUS IN CANADA

Although *Polydora* infection may not affect the condition of meats it does affect the market value of oysters in another way. When the oysters are opened the appearance of blisters as large as some of those found on Bras d'Or lake shells is unappetizing, and if they are broken the stinking mud which they contain escapes over the meat and is quite disgusting. Badly infected Bras d'Or lakes oysters are consequently unfit for the half-shell trade.

The records show that *Polydora* is already widely distributed in our oyster areas so there is no danger involved in transferring badly infected oysters to areas where the pest is not apparent. In this respect our blister worm problem

is quite different from that involving the oyster drill (*Urosalpinx*) which at present has a highly restricted distribution and is liable to be introduced through human agencies to areas where it might become enormously destructive.

Considering the results of this investigation and the enquiry among the fishermen, it appears that the importance of *Polydora* to the Canadian Atlantic oyster industry is limited and stable and is likely to remain so unless hydrographic conditions change.

TABLE III. Summary of analysis of data on the index of condition of oysters infected and uninfected by *Polydora*.

			Degrees of freedom (df)
Within-lots difference between mean index for infected and for uninfected oysters	$(\bar{I}_i - \bar{I}_u) = d$		
Weighting factor for "d" for each lot	$\frac{n_u - n_i}{n_u + n_i} = w$		
Weighted mean difference between means	$\frac{\Sigma wd}{\Sigma w} = \bar{d} =$	+0.67	
Weighted mean square or interaction mean square	$\frac{\Sigma w(d-\bar{d})^2}{df} =$	372.42	17
Pooled within-lots variance for uninfected	$\frac{\Sigma(Iu - \bar{I}u)^2}{\text{Pooled df for uninfected}} =$	381.57	87
Pooled within-lots variance for infected	$\frac{\Sigma(I_i - \bar{I}_i)^2}{\text{Pooled df for infected}} =$	314.23	40
Pooled within-lots variance for infected and uninfected "sampling error"	$\frac{\Sigma(I_u - \bar{I}_u)^2 + \Sigma(I_i - \bar{I}_i)^2}{\text{Pooled df for uninfected} + \text{Pooled df for infected}} =$	360.36	127
Test for interaction	$\frac{\text{Weighted mean square}}{\text{Pooled variance for uninfected and infected}} = F =$	1.03	17 127
Test for homogeneity	$\frac{\text{Pooled within-lots variance for uninfected}}{\text{Pooled within-lots variance for infected}} = F =$	1.21	87 40
Test for significance of d as a departure from zero	$t = \frac{\bar{d}}{\text{weighted mean square}/\Sigma w} =$	0.19	17

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